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THE EFFECT OF NINE DAYS OF RECUMBENCY, WITH AND WITHOUT EXERCISE, ON THE REDISTRIBUTION OF BODY FLUIDS AND ELECTROLYTES, RENAL FUNCTION AND METABOLISM

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for
THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C.
Contract No. NGR 05-004-021
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Foreword

The advent of man's encounter with space flight and the problem of weightlessness has stimulated a renewed interest in the physiology of disuse. Aircraft flying Keplerian parabolas have probably provided the greatest quantity of data regarding the biological effects of weightlessness. However, these data represent extremely short experimental periods of 15 - 45 seconds. Although some data have been collected on the astronauts involved in recent manned space flight, the present state of knowledge concerning normal anatomical and functional response to prolonged space flight, *per se*, is negligible (McCally and Graveline, 1963).

Since it is virtually impossible to simulate an agravity environment in an earth-bound laboratory, two analogous methods have been employed for the investigation of the agravitational state, viz., bed rest and water immersion. Data collected in earlier studies utilizing the above analogies are being reinvestigated and extrapolated with reference to the weightless state. The interpretation of these data suggests that prolonged weightlessness will have a deconditioning effect. The exact etiology and magnitude of this deconditioning remains only partially answered.

The present investigation developed as a natural outgrowth of an earlier cooperative study completed at the Ames Research Center, California, with Dr. John Greenleaf. The primary question concerns that of water balance, or more specifically, the apparent tendency of astronauts to become hypohydrated (average 3.34% loss of body weight) following a short period in the weightless state (Webb, 1967). Any question of water balance necessarily involves the study of the complex interaction of a number of major physiological systems. Consequently, the present investigation included observations on body fluid compartments, renal function, water and electrolyte exchange, and metabolic changes.

Bed rest was selected as the experimental analog to simulate the weightless state. In recumbency the hydrostatic pressure effect on the body fluid is reduced to one-seventh that of standing erect (McCally and Lawton, 1963). Under these conditions, the circulatory system approaches a functional agravity state. In addition, there is a redistribution of body fluids between the anatomical compartments, decreased demands for musculo-skeletal activity, decreased metabolic rate and catabolism.

Three basic questions are raised in the present investigation:

1. To what extent does recumbency alter the anatomical body fluid compartments, renal function, water and electrolyte exchange and metabolism?
2. Will dynamic exercise performed while in the recumbent posture attenuate the effects of recumbency?
3. To what extent are the procedures employed in the present investigation applicable to the onboard situation, i.e., how practical and how repeatable are the procedures?

The hypothesis posed at the onset of this investigation was that prolonged recumbency produces a deconditioning of certain homeostatic and adaptive responses to orthostatic changes. It was supposed that during recumbency the lack of normal gravitational stimuli to regulatory systems resulted in relaxation to the extent of an impaired ability to maintain these homeostatic systems in their proper balance. Exercising on a bicycle ergometer resembles an orthostatic change in that a redistribution of blood volume from the central circulatory system to the leg muscles occurs when exercise is initiated. In this study, an ergometer was used in two daily bouts of exercise with subjects in the horizontal position. The efficacy of this variable was assessed by comparing the changes in body fluid and related regulatory systems that occurred in non-exercising, recumbent subjects with subjects who performed the daily bouts of exercise during the period of recumbency. It was anticipated that such dynamic exercise would cause an attenuation of the disuse effect of recumbency.

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PART I

EXPERIMENTAL DESIGN

Ten healthy young college males participated in a 27 day experiment during the summer of 1967. The experiment included a 10 day period of dietary equilibration (pre-bed rest), a nine and one-half day period of bed rest, and a seven day period of recovery (post-bed rest) (refer to flow chart, Appendix I).

During the equilibration period, the subjects were placed on a controlled dietary regimen of known caloric, electrolyte and water content, while all experimental measurements were made serially to establish baseline values. Since the subjects were permitted to continue their respective daily routines during this period, a daily activity log was kept by all subjects. The activity-rest pattern of all but one subject was observed to be quite typical for young men.

The subjects assumed the recumbent position without physical restraints during the following nine and one-half days, and continued all vital activities, including eating and elimination in the horizontal position. The dietary regimen initiated during the equilibration period was continued throughout the bed rest period, but was modified with reference to caloric, electrolyte and water content in order to maintain a net balance under the altered metabolic demands of recumbency. The subjects were monitored around the clock during the bed rest period, with all necessary transportation of subjects done on a hospital guerney. Following a standard series of tests on the morning of the 20th day, the subjects resumed their normal pre-bed rest ambulatory activity pattern. During this seven day recovery period, they were allowed to eat and drink ad libitum, but were required to maintain a detailed log of all activity and fluid and food intake.

At the beginning of the experiment, the 10 subjects were subdivided into three groups and assigned coded identification numbers for ease of experimental sample identification and subsequent statistical treatment. Four subjects served as "exercise" subjects (1, 3, 5, and 7) during the bed rest period, while four others served as internal controls, or "non-exercisers" (2, 4, 6, and 8). The remaining two subjects, external controls (10 and 12), continued their normal ambulatory activity pattern throughout the 27 experimental days.

To avoid overtaxing facility, equipment and laboratory support, a staggered time schedule covering a period of 49 days was employed within the framework of the experimental design. Subjects began the experiment in four separate subgroups as follows: 1 and 2; 3, 4, and 10; 5 and 6; and 7, 8, and 12 (see Appendix I). Three days intervened between initiation of the experimental protocol for the first two subgroups, and 19 days between the second and third subgroups, while the fourth subgroup began three days after the third. The three day spacing helped facilitate the dietary preparation, which was planned on a three day cyclic basis. The 19 day spacing permitted the first two subgroups to complete their bed rest period before the third subgroup began. The staggered time schedule permitted uniform treatment within the outlined experimental design and protocol for all four subgroups.

Biological samples were collected serially on designated days of the experiment as outlined in the experimental flow chart, Appendix I. Twenty-four hour pooled urine samples were initiated at 0700 immediately after the subjects awakened. Basal blood samples were routinely drawn at the end of the 24 hour urine collection period, while a series of renal function tests were also completed at this time. Twenty-four hour pooled urine samples were not collected on days of renal function testing because of the distortion of normal renal physiology caused by the standardized water load of 1.3 liters given the subjects prior to these tests. A series of pilot studies established the validity of the procedures employed in the current investigation, viz., that if the renal tests were completed in the morning, normal physiological values were obtained 24 hours later. Therefore, it was assumed in this investigation that the 24 hour pooled urine of the day following a renal test procedure was normal, since the collections began on the morning of the day following the large diuresis produced by the water load.

The number of renal function tests performed on each subject during the course of the 27 day experimental period was limited to a large extent by the number of venipunctures that the subjects' veins could tolerate. In addition, a gradual decrease in the subjects' tolerance for the test was observed. The procedures involved in the renal function tests required the insertion of two needles; (1) an 18 gauge, 1½ inch catheter, and (2) a 20 gauge, 1 inch hypodermic needle. Six renal function tests and three additional venipunctures were thought to be the maximum allowable trauma to the veins during the 27 day period. The renal function tests were performed once before, three times during and twice after bed rest. In addition, during the pilot studies, a single test was run on seven of the eight bed rest subjects.

A total of nine blood samples spaced throughout the three experimental periods were drawn for analysis of blood constituents. The six samples drawn on renal function days corresponded with the previous days 24 hour pooled collection of urine specimens. These also served as basal values for post-exercise determinations. The three blood samples that were not drawn on renal function test days corresponded to the beginning of the 24 hour pooled urine collection period.

During the nine day period of recumbency, four subjects exercised twice daily. In order to study the effects of this exercise, renal function tests were designed to include resting, exercise, and post-exercise periods of sample collection. Hence, the exercise subjects completed one of their 30 minute daily exercise bouts during the test. In addition, the control subjects completed this bout of exercise on day 10 of the pre-bed rest and on day 21 and 27 of the post-bed rest periods.

All measurements made on experimental day 20 served to indicate terminal bed rest values. Of necessity, some of the measurements, viz., K_{40}, lean body mass, strength, and the prescribed anthropometric measurements, were obtained after the subjects assumed the upright posture. However, these data were collected in the post-absorptive state immediately after ambulation began.

As previously mentioned, this investigation was designed to ascertain the interrelation of several physiological systems, thus necessitating the measurement of many parameters. For ease of discussion, these parameters have been organized by the various physiological systems to which they are related and are reported and discussed in an order consistent with the outline given below.

Outline of Experimental Parameters

I. Fluid Exchange and Related Parameters
   A. Fluid Gain (ml/24 hour)
      1. Fluid consumption controlled: Days 1-19
      2. Fluid consumption *ad libitum*: Days 20-26
   B. Fluid Loss
      1. Urine excretion (ml/24 hour)
      2. 24 hour evaporative water loss (gms/24 hour)
         a. Night Insensible Water Loss (IWL) (gms/hour)
         b. Day Insensible Water Loss (IWL): Days 11-19 (gms/hr)
         c. Active perspiration (gms/hr)
      3. Urine flow rate
         a. Day rate 0700-2300
         b. Night rate 2300-0700
         c. Diuresis rate during renal function tests: Days 10,12,15,19,21,27
   C. Body Weight
      1. Morning (0700)
      2. Night (2300)
   D. Fecal Production with Low Residue Diets: Days 1-19
      1. Frequency
      2. Weight during bed rest
II. Body Fluid Volumes and Blood Chemistry
   A. Total Body Water: Tritiated Water (liters)
   B. RISA Blood Volume (liters)
      1. Plasma volume
      2. Hematocrit (%)
   C. Blood Chemistry
      1. Electrolyte
         a. Sodium (mEq/L)
         b. Potassium (mEq/L)
         c. Chloride (mEq/L)
      2. Osmolality (mOsm/L)
      3. Creatinine (mg%)
III. Renal Function
   A. Renal Clearance
      1. Renal plasma flow (ml/min)
      2. Glomerular filtration rate (ml/min)
         a. Creatinine
         b. Inulin
   B. Urine Composition
      1. Electrolytes
         a. Sodium
            1) concentration (mEq/L)
            2) output per day (mEq/day)
            3) rate per day (μEq/min)
         b. Potassium
            1) concentration (mEq/L)
            2) output per day (mEq/day)
            3) rate per day (μEq/min)
         c. Chloride
            1) concentration (mEq/L)
            2) output per day (mEq/day)
            3) rate per day (μEq/min)

2. Osmolality
   a. mOsm/L
   b. mOsm/day
3. Aldosterone concentration (μgms/24 hour)
4. Creatinine
   a. mg/100ml
   b. gms per day

IV. Metabolic Measurements
   A. Caloric Intake Control (calories)
   B. Electrolyte Metabolism (mEq)
      1. Sodium
      2. Potassium
      3. Chloride
   C. Respiratory Metabolism
      1. Basal metabolism
         a. Ventilation (L/min)
         b. Respiratory rate/min
         c. True oxygen (%)
         d. Respiratory quotient
         e. Oxygen consumed (ml/min and ml/kg/min)
      2. Resting metabolism
         a. Ventilation/min
         b. Respiratory rate/min
         c. True oxygen (%)
         d. Respiratory quotient
         e. Oxygen consumed (ml/min and ml/kg/min)

V. Anthropometric Measurements
   A. Body Composition
      1. K_{40} (total body count in gms of potassium)
      2. Body fat (as % of body weight)
      3. Lean body mass (kg)
         a. Densitometry by immersion
         b. Skinfolds
   B. Body Circumferences (cm)
      1. Calf
      2. Thigh
      3. Upper arm (relaxed and contracted)
      4. Chest
      5. Waist
   C. Muscle Strengths
      1. Hand grip (kg)
      2. Knee extension (kg)
      3. Plantar flexion (kg)
   D. Respiratory Volumes
      1. Vital capacity
      2. Residual lung volume

VI. Physiological Response to Exercise
   A. Renal Function
      1. Renal plasma flow (ml/min)
         a. Pre-exercise
         b. Exercise
         c. Post-exercise
      2. Glomerular filtration rate (creatinine) (ml/min)
         a. Pre-exercise
         b. Post-exercise
      3. Electrolyte excretion rate (μEq/min)
         a. Sodium
            1) pre-exercise
            2) post-exercise
         b. Potassium
            1) pre-exercise
            2) post-exercise

c. Chloride
1) pre-exercise
2) post-exercise
4. Osmolality
a. Serum osmolality
1) pre-exercise
2) post-exercise
b. Urinary osmolality
1) pre-exercise
2) post-exercise

B. Respiratory Metabolism
1. First 10 minutes of 30 minute bout
a. Ventilation/min
b. Respiratory rate/min
c. True oxygen (%)
d. Respiratory quotient
e. Oxygen consumed (L/min)
2. Second 10 minutes of 30 minute bout
a. Ventilation (L/min)
b. Respiratory rate/min
c. True oxygen (%)
d. Respiratory quotient
e. Oxygen consumed (L/min)
3. Third 10 minutes of 30 minute bout
a. Ventilation (L/min)
b. Respiratory rate/min
c. True oxygen (%)
d. Respiratory quotient
e. Oxygen consumed (L/min)

C. Heart Rate during Exercise
1. Pre-exercise
2. Exercise - 10 min
3. Exercise - 20 min
4. Exercise - 30 min

Appendix I: Calendar of Experimental Procedures

To permit an optimum of time and energy both during the experimental period and for the subsequent analytical procedures the subjects will begin the experiment in pairs; one exercise and one non-exercise subject per pair.

The experiment has three major subdivisions in time and condition: a) equilibration or dietary control, b) recumbent bed rest, exercise or non-exercise, and c) post recumbent bed rest. The paired subjects' time schedule for the above periods are as follows:

		Equilibration	Bed Rest	Recovery
A	Subjects 1,2	June 26 - 5 July	6 - 14 July	15 - 22 July
B	Subjects 3,4 and 10	June 29 - 8 July	9 - 17 July	18 - 25 July
C	Subjects 5,6	July 16 - 25 July	26 - 4 August	5 - 11 August
D	Subjects 7,8 and 12	July 19 - 28 July	29 - 7 August	8 - 14 August

Sample Collection and Subject Responsibilities

Day 0: Subjects report to Health Center at 9:00 p.m.
1: Basal blood, BMR, begin controlled diet, 24-hour urine sample
2-3: Subjects continue daily activities
4: Subjects report at 9:00 p.m., resting metabolism
5: Basal blood, BMR, 24-hour urine sample
6-8: Continue daily activities
9: LBM, anthropometric measurements, 24-hour urine sample, resting metabolism
10: BMR, renal function tests, blood volume, total body water and total body potassium
11: Bed rest begins, BMR, 24-hour urine sample
12: BMR, renal function tests, blood volume
13: BMR
14: BMR, 24-hour urine sample
15: BMR, renal function tests, blood volume
16: BMR, 24-hour urine sample
17: BMR
18: BMR, 24-hour urine sample
19: BMR, renal function test
20: BMR, subjects resume ambulatory activities, food and beverages _ad_ libitum, LBM, 24-hour urine sample, report at 9:00 p.m., resting metabolism
21: BMR, renal function tests
22: Report at 9:00 p.m., resting metabolism
23: BMR, basal blood, 24-hour urine sample
24-25: Continue daily activities
26: 24-hour urine sample, report at 9:00 p.m., resting metabolism
27: BMR, renal function tests, blood volume

Experimental Flow Chart

Experimental Parameters	Experimental Day																										
	(Pre-Bed Rest Equil)										(Bed Rest)									(Post-Bed Rest Recovery)							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
<u>Fluid Balance</u>																											
intake controlled	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
intake *ad lib*																				x	x	x	x	x	x	x	x
urine volume	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
urine flow rate	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
24 hour perspiration	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
daytime perspiration				x					x	x										x		x				x	
day IWL											x	x	x	x	x	x	x	x	x								
day active perspiration											x	x	x	x	x	x	x	x	x								
night IWL				x					x	x	x	x	x	x	x	x	x	x	x	x		x				x	
a.m. body weight	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
p.m. body weight				x					x	x	x	x	x	x	x	x	x	x	x	x		x				x	
<u>Body Fluid Analysis</u>																											
T_2O										x									x								
D_2O									x											x						x	
RISA										x		x			x				x		x						x
electrolytes & Osm(bsl)	x				x					x		x			x				x		x		x				x
Osm(post-exercise)										x		x			x				x		x						x
creatinine										x		x							x		x						x

Experimental Flow Chart

Experimental Parameters	Experimental Day		(Pre-Bed Rest Equil)										(Bed Rest)									(Post-Bed Rest Recovery)					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
<u>Renal Function</u>																											
RPF (PAH)										x		x			x				x		x						x
GFR (inulin)										x		x			x				x		x						x
GFR (creatinine)										x		x			x				x		x						x
GFR (creatinine 24 hr)	x				x				x		x	x	x	x		x		x		x			x				
electrolytes (24 hr)	x				x				x		x			x		x		x		x			x			x	
electrolytes (ex)										x		x			x				x		x						x
osmolality (24 hr)	x				x				x		x			x				x		x			x			x	
osmolality (ex)										x		x			x				x		x						x
aldosterone										x									x								
creatinine (24 hr)	x				x				x		x	x	x	x		x		x		x			x				
<u>Metabolism</u>																											
caloric control	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
basal metabolism					x					x	x	x	x	x	x	x	x	x	x	x	x		x				x
resting metabolism				x					x	x										x		x				x	
exercise metabolism										x		x			x				x		x						x
<u>Anthropometric Data</u>																											
K40					x					x										x						x	
LBM, circumference, strength & vital cap	x								x											x						x	

APPENDIX II: NASA PROJECT PERSONNEL

A. Investigators

1. Dr. Edmund M. Bernauer
2. Dr. William C. Adams

B. Laboratory Staff

1.	Mr. James H. Fuller	Research Assistant and Experimental Supervisor
2.	Mrs. Margaret Bolefahr	Medical Technologist
3.	Mr. William Meehan	Laboratory Technician
4.	Mr. David Crew	Laboratory Technician
5.	Mr. Craig Williams	Laboratory Technician
6.	Miss Judy Ellis	Laboratory Assistant
7.	Miss Janet Hoyt	Laboratory Assistant
8.	Mr. John Pletcher	Laboratory Assistant
9.	Mr. Phillip Cello	Laboratory Helper
10.	Miss Sara Crew	Laboratory Helper
11.	Miss Susan Ryan	Laboratory Helper

C. Research Associates

1.	Dr. Loren Carlson	School of Medicine, U.C. Davis
2.	Dr. Thomas Cooper	Director, Student Health Center, U.C. Davis
3.	Dr. Thomas Elliott	Clinical Supervisor, Student Health Center, U.C. Davis
4.	Dr. John Loofbourow	Clinical Supervisor, Student Health Center, U.C. Davis

D. Research Collaboration

1.	Miss Lynn Ausman	Diet Formulation, Dept. of Food Science, U.C. Davis
2.	Dr. Edward Biglieri	Urinary Aldosterone, San Francisco
3.	Dr. Rene Hardre	Blood Volume (RISA), Sacramento County Hospital
4.	Dr. Marvin Goldman	Whole Body Counting (K-40), Radiobiology Division, AEC Research Station, U.C. Davis
5.	Dr. Jiro Kaneko	Thyroid Uptake, I-131, School of Veterinary Medicine, U.C. Davis
6.	Dr. Richard Walters	Computer Program, Regional Medical Programs, U.C. Davis
7.	Dr. Ove Wilson	Thyroid Uptake, I-131, School of Medicine, U.C. Davis

PART II

DESCRIPTION OF METHODS AND MATERIALS

Water Balance

Water balance was calculated by a modified version of the Peters-Passmore equation and was expressed for a 24 hour period (Consolazio, Johnson and Pecora, 1963, pp. 317-318). The equation (with all units expressed in grams) is as follows:

Water Balance =

$$W_t - (\text{Solids}_{in} - \text{Solids}_{out}) - (O_2\text{abs} - CO_2\text{excr}) + H_2O \text{ met(which is } 0.89\ O_2\text{abs} + 1.309\ CO_2\text{excr} + 1.04\text{Nu}).$$

The modified equation is described in Appendix V. During bed rest, the subjects were weighed in the recumbent position to the nearest 20 grams on a mobile hydraulic Fairbanks-Morse scale (see Figure 2.1). A custom made interchangeable platform for the scale served to support the subjects in the horizontal position during defecation and to determine the net weight change, i.e, fecal weight (see Figure 2.2). This eliminated the muscular effort involved in using a bed pan. All foods and beverages consumed were of known water content during the pre-bed rest and bed rest periods. During these two experimental periods subjects were placed on regulated constant volume intake, and a rough water balance was calculated daily to determine the state of hydration. If a negative balance developed, adequate water was given to replace the fluids lost and to readjust water balance. By utilizing this procedure, each subject's state of water balance was known at the beginning of bed rest. Subjects were instructed to urinate before weighing, both in the morning upon arising and at night before retiring. During bed rest if the subject could not urinate at these prescribed times, the urine volume that was collected later was divided by the time since the last voiding, and the estimated volume at the time of weighing was subtracted from the weight. Body weights were recorded to the nearest 20 grams in the morning (0700) and at night (2200). Exact fecal weights were determined only during bed rest. The low residue diet produced a small and fairly constant fecal weight that could be estimated on a daily basis within 20 grams for a given subject. During the post-bed rest period subjects reported in their daily logs the type and quantity of food consumed,

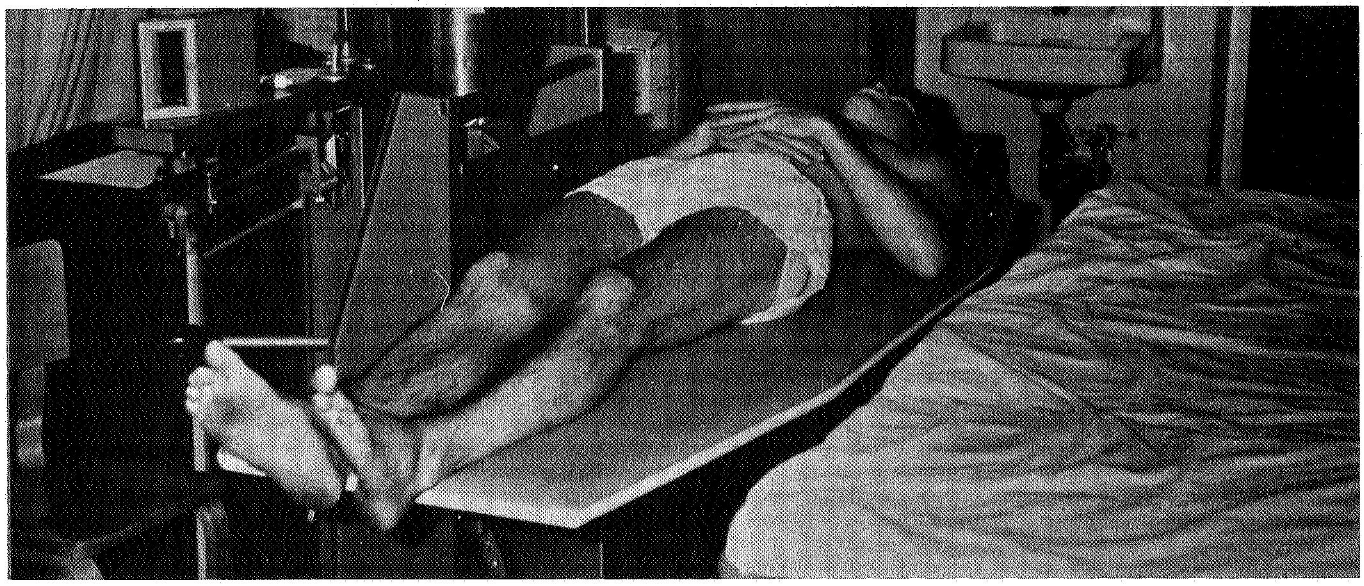

FIG. 2.1. MOBILE SCALE. Scale for weighing subjects in recumbent position. The supporting platform could be raised for standing weights of subjects during ambulatory periods.

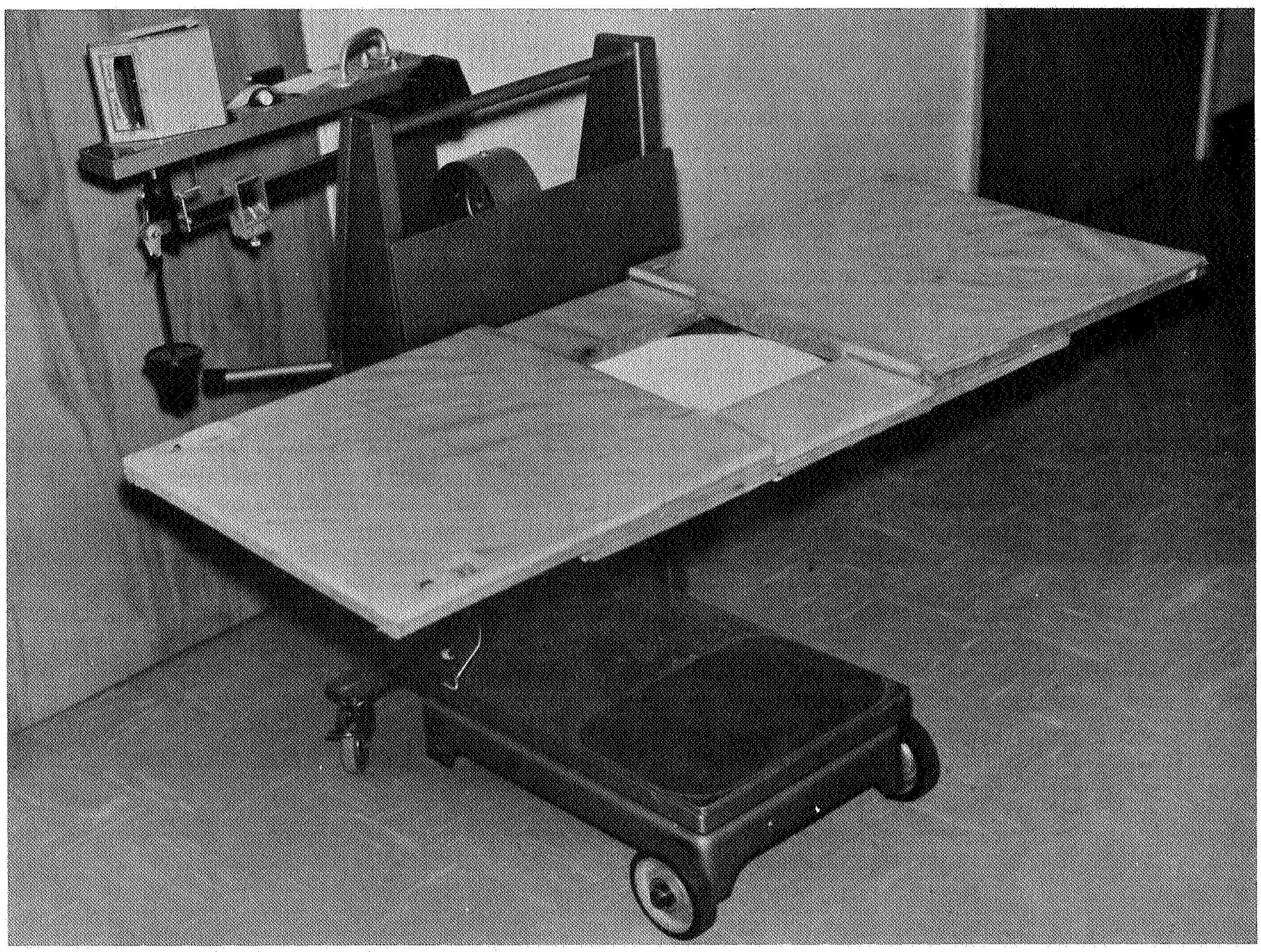

FIG. 2.2. CUSTOM MADE PLATFORM. The platform above was exchanged for platform seen in FIG. 2.1 and served to support subjects while they defecated. The use of such a platform required little muscular effort in the recumbent position.

from which the total body water consumed was calculated for each day.[1] Active sweat loss was measured in exercise subjects during bed rest by pre- and post-exercise weights.

Other Water Loss

The ΔW_t factor given above in the Peters-Passmore equation was invalidated on five separate occasions by extraordinary weight changes, viz., water loss by vomitus and mild diarrhea; the former occurring twice and the latter three times. In each instance, the water loss was collected and weighed. The weight was added to the next morning's weight for the purpose of determining water balance, i.e., the calculation of water balance was made on the basis of the corrected weight. The uncorrected weight as first measured served as the reference weight to calculate the water balance for the subsequent 24 hour period.

Blood loss during the entire 27 day experiment was approximately 441 ml for each subject. A total of 95 ml of blood was drawn during pre-bed rest, 195 ml during bed rest, and 150 ml during post-bed rest. Water loss via blood letting was used only in expressing corrected water balance for the three complete periods, rather than on a daily basis.

Body Fluids

Total body water was measured by the dilution principle by injecting 1.0 millicurie of tritiated water (T_2O) (HTO) intravenously.[2] A pre-injection blood sample was drawn, the tritium injected and subsequent blood samples were taken at two, three, and four hours post-injection. Plasma was analyzed for radioactive tritium with a scintillation counter. The exact amount injected was calculated by pre - post weight difference of the syringe checked against volume (Appendix VI).

Blood volume was measured by the dilution principle using an intravenous injection of 1-2 millicurie of radio-iodine labeled serum albumin.[3] After the pre-injection blood sample was drawn, a second sample was taken 10-15 minutes later for subsequent measurement of radiation activity. The syringe was placed in a Volumetron and the amount of I-131 in it was counted before and after injection to determine the amount of the agent injected. Packed cell volume (hematocrit) was determined from the same sample, and plasma volume was determined by difference (for details, see Appendix VII). Aliquots of all blood samples were taken and immediately brought to the Human Performance Laboratory where they were separated for chemical analyses, including those on the infusion chemicals (PAH and inulin). Since all analyses could not be completed on the experimental day, a portion of the serum was frozen and stored. Serum sodium and potassium were measured with a lithium internal standard by flame photometry[4] and serum chloride by a chloridometer[5] with sodium chloride as a standard. Osmolarity was determined with sodium chloride standards by freezing point depression on an osmometer[6]. Creatinine was determined by the alkaline picric acid method (Consolazio and Johnson, 1960) and color read on a spectrophotometer[7].

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[1]Nutritive Value of Foods, USDA Home and Garden Bulletin #72.
[2]Tritiated water from Abbott Laboratories, Chicago, Illinois.
[3]RISA, Mallinckrodt Chemical Works (Nuclear Division), St. Louis, Missouri.
[4]Beckman Flame Photometer.
[5]Buchler-Cattone Chloridometer
[6]Advanced Osmometer, Advanced Instruments, Inc.
[7]Beckman Spectrophotometer B.

Renal Function

Renal plasma flow (RPF) was determined with Para-amino hippurate (PAH)[8]. PAH was injected in a priming solution of sufficient concentration to bring blood levels to 1.5 to 2.5 mg%, and sustained at that level by infusing a solution of PAH and saline with a Sage infusion pump[9] at a rate of 1.6 ml/min. for approximately 2 hours. The protocol developed in pilot experiments was used, i.e., two resting clearances of 15 min. duration, one exercising sample of 30 min. duration, and two post-exercise samples, one 15 min. and one 30 min. in duration. (See Appendix III for a more complete description.) Plasma and urine concentrations of PAH were measured by the method of Smith (1956).

Glomerular filtration rate (GFR) was measured by the clearance of inulin[10] using the Resorcinal method (Schreiner, 1950). The clearance tests of inulin were identical to that of PAH.

Creatinine was measured in serum, as described above, on all six renal function test days. Serum levels were determined roughly coincident to urine determinations from 24 hour pools. Urine creatinine was measured on three different sample specimens, viz., in 24 hour urine, in the blank urine that preceded an infusion of PAH and inulin, and in post-exercise urine. GFR was also determined on these three occasions.

Urine was collected in 24 hour pools unless a urine specimen was needed for a specific analysis, in which case a measured 30 ml aliquot was withdrawn and noted in the log for purposes of recording 24 hour urine production. The remainder was then added to the pooled urine. Using the same analytical procedures employed for serum, urine electrolytes, osmolality, and creatinine were analyzed. Urine for determination of aldosterone was frozen and sent to San Francisco County Hospital for measurement at the conclusion of the project.[11]

Metabolism

Dietary regimens were written for all subjects and standardized to satisfy the caloric needs of basal metabolism, daily routine activities, large muscle activity (exercise) and the energy needs of metabolising food (i.e., Specific Dynamic Action) according to procedures outlined by Bogert (1966) and Consolazio, Johnson, and Pecora (1963). Three separate dietary regimens were written based on 60, 70, and 80 kg body weights corresponding to intakes of 3000, 3450, and 3850 Calories, respectively (see Appendix VIII). Other than selecting foods of low residue, the selection was made from the more common food products to minimize the possibility of precipitating ingestive or digestive problems. All dietary calculations were made by a graduate dietition. The food was prepared and served by the University hospital staff.

The diets were also adjusted for the transition from the normal ambulatory pre-bed rest period to the bed rest period. Two separate adjustments were made, one for the exercise bed rest and the second for the non-exercise bed rest subjects. The adjustments included caloric, water, and salt intake. Sodium and potassium chloride were weighed daily and placed in individual dispensers to supplement the electrolyte content of the diets, i.e., each of the three daily diets were supplemented to a standard level and that level of intake was maintained throughout each period. The

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[8]Sodium para-amino hippurate, 20% normal saline suspension, from Merck, Sharp and Dome, South San Francisco, California.

[9]Fixed speed, double syringe, 50 ml capacity infusion pump, Model 249-2, Sage Instruments, Inc., White Plains, New York.

[10]Inulin, 10% normal saline suspension, from Warner Chilcott, Scientific Products, Inc., Menlo Park, California.

[11]Chemical determination under the direction of Edward Biglieri, Clinical Studies Center.

total amount of sodium and potassium during the pre-bed rest equilibration period was 6.5 (286 mEq) and 4.75 (126 mEq) grams, respectively, for all subjects. The daily dosage was decreased during the bed rest period in proportion to the reduction of the caloric intake (see Appendix VIII). It was the purpose of the investigation to maintain the subjects in a state of normal hydration. Daily adjustments were made for water intake based on the calculated daily water balance. As with caloric and salt intake, this was standardized initially on the basis of body weight. When bed rest began, the water intake was reduced for non-exercise subjects and increased for exercise subjects based on the estimated needs during either state of activity.

Respiratory Metabolism

Respiratory metabolism was measured in three states: basal, resting, and exercise. During the pre-bed rest period, subjects were scheduled periodically to sleep overnight at the experimental facility. On these occasions, respiratory metabolsim was measured in the evening under resting conditions prior to retiring and in the morning under basal conditions just after they awakened. These measurements were made by the open-circuit method employing either a 120 liter Tissot tank or Kofrani-Michaelis portable K-M respiratory gas meters that were routinely calibrated (pp. 48-50, Consolazio, Johnson, and Pecora, 1963).

During the equilibration and the recovery periods, exercise, respiratory, and metabolism measurements were made on all subjects in conjunction with the renal function tests. Individual work loads for the recumbent bicycle ergometer exercise were established during a pre-experiment upright bicycle ergometer ride by direct measurement, or by predicted values on the basis of heart rate response after the method of Astrand and Rhyming (1954). Some minor adjustments in work load were made on the basis of LBM and strength tests results in a further attempt to insure that the loads were of similar relative difficulty for each subject.

During the bed rest period, the experimental exercise subjects performed their individually prescribed work load for 30 min. twice daily, once in the morning and once in the afternoon (see Figure 2.3). On days of renal function tests, one of the scheduled 30 min. bouts was satisfied during the test, with exercise metabolism samples collected concurrently.

During the exercise tests, respiratory metabolism was measured by the open-circuit method using the portable K-M meter (see Figure 2.4). Aliquots of expired air were analyzed from each of three 10 min. collection periods during the exercise bout. Percent oxygen was determined with a Beckman Oxygen Analyzer (model D_2) and percent CO_2 by a Thermal Gasanalyzer (Godart). True O_2 and RQ values and O_2 intake/unit time were calculated after standard procedures using pulmonary ventilation and the above measurements (pp. 5-11, Consolazio, Johnson, and Pecora, 1963). On days when no renal function tests were run, only heart rate was recorded at the end of each of the three 10 min. intervals during exercise.

Subject	1	3	5	7	2	4	6	8	10	12
Work load (kpm)	850	750	725	900	750	725	700	800	725	825
Work load (watts)	139	126	119	147	123	119	114	131	119	135

TABLE 2.1. WORK LOADS FOR STANDARD 30 MINUTE EXERCISE BOUTS. Work load in recumbent exercise was established on the basis of preliminary tests in the sitting position at approximately 50% maximum oxygen uptake. This load was used by subjects 1, 3, 5, and 7 twice daily during the 9 days of recumbency, and by subjects 2, 4, 6, 8, 10, and 12 in renal tests before and after bed rest.

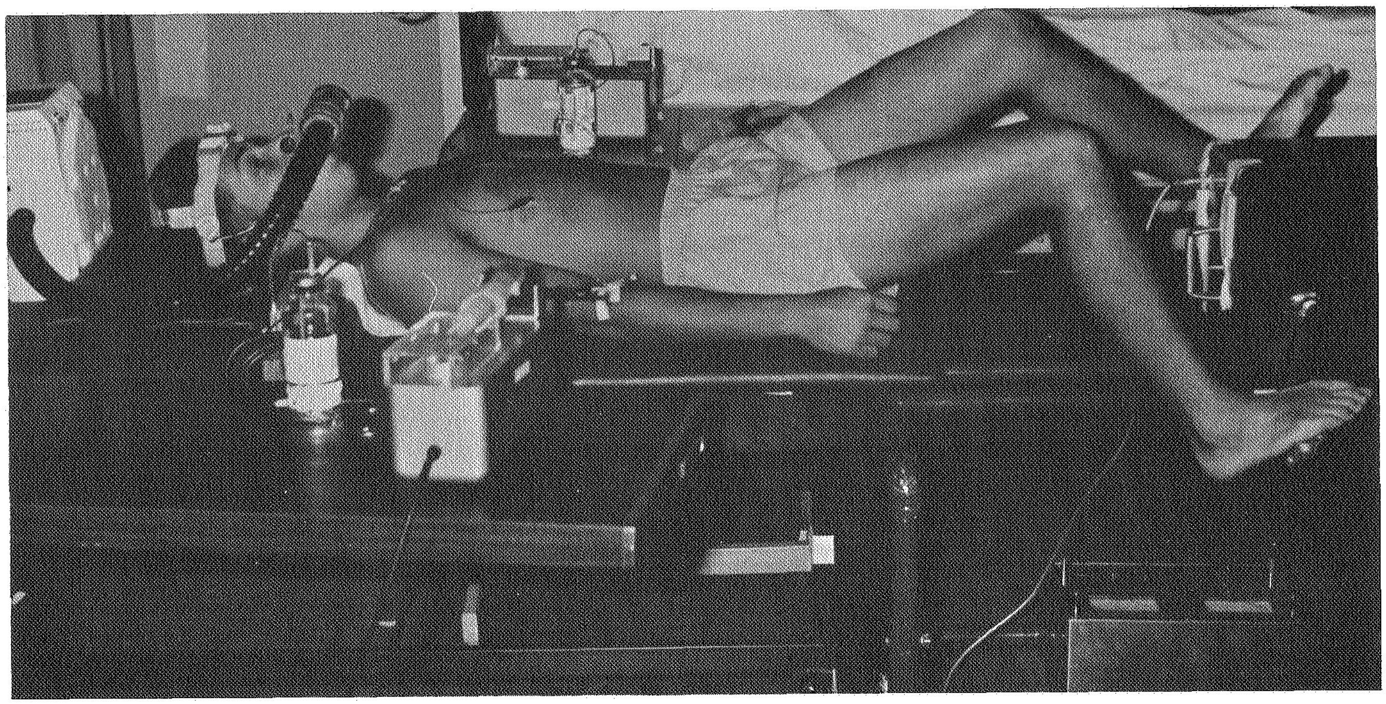

FIG. 2.3. APPARATUS FOR RECUMBENT EXERCISE. A Collins ergometer placed on an adjustable frame allowed subjects to exercise in the horizontal position. The frame was constructed so that the average position of the legs was parallel with the heart in order to assure minimal gravitational effects on the cardiovascular system during exercise.

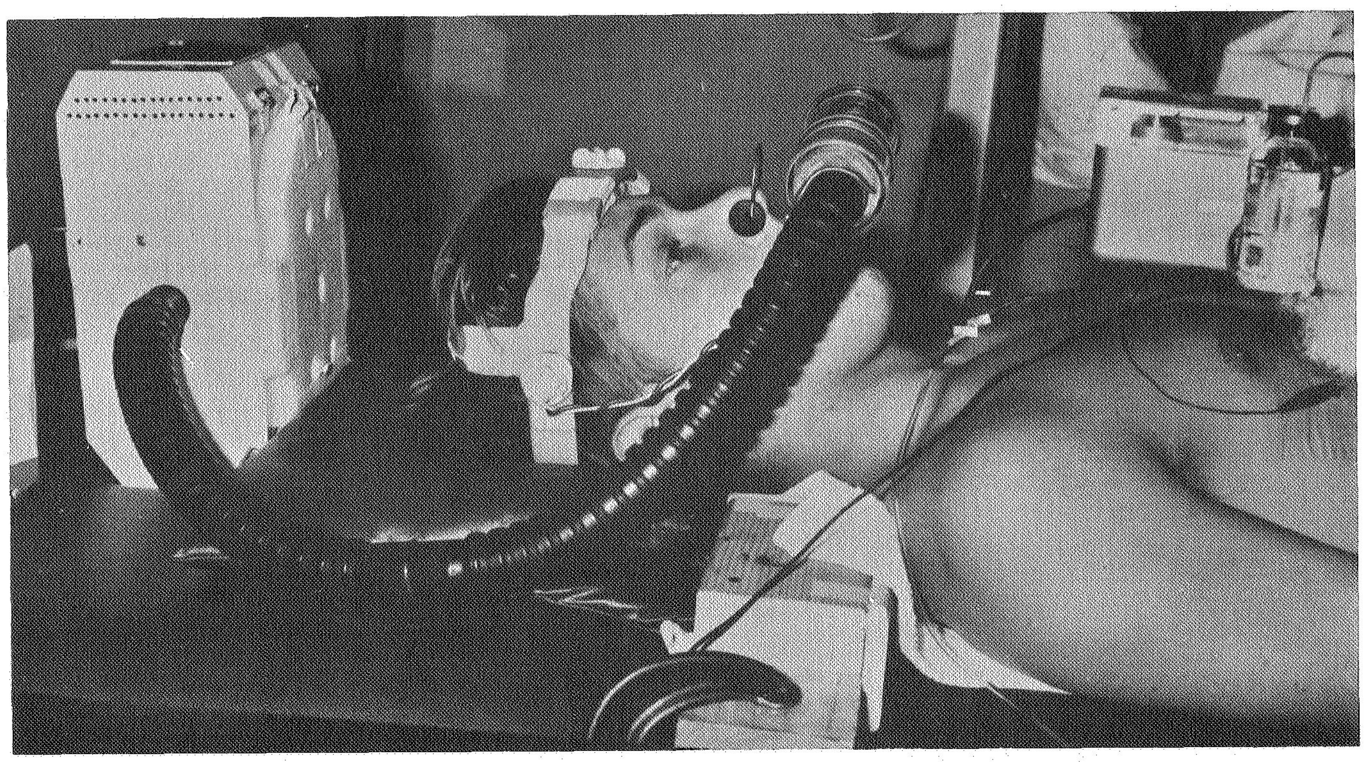

FIG. 2.4. HEAD GEAR FOR RESPIRATORY APPARATUS. During exercise, a continuous collection of expired air was collected using a Collins two-way plastic "J" valve and a portable K-M meter.

Anthropometric Measurements

Body density, selected anthropometric measurements, isometric muscle strengths, and vital capacity were all measured on experimental days 9, 20, and 26. Body composition was estimated by the water immersion technique (see Appendix X), by the skinfold calipers method (Pascale, 1956), and by whole body potassium-40 counting. In the latter technique, a whole body scintillation counter was utilized to determine total body radioactivity.[12] The counting apparatus consisted of a 20 X 10 cm. sodium iodide detector optically coupled to three photo multipliers and a preamplifier which had pulsite distributions to an RIDL 400 channel multichannel analyzer. The detector was housed in a 5½ in. diameter cylindrical counting chamber of 5½ in. low background iron, the inner surface of which was lined with copper cadmium and lead to reduce scatter radiation. The subjects were positioned in a vinyl beach chair modified to describe a 90 cm. arc from the face of the crystal. Two additional chairs were fabricated for background and standard measurements. The background measurements were derived by the counting of 70 kg of granulated sugar arranged in approximately a human form. A similar sugar phantom was prepared in which potassium chloride had been carefully admixed to provide a concentration of 2 g potassium/Kg sugar distributed in a cloth suit made to simulate a human form. In addition to days 9, 20, and 26, each subject was counted on day five. Background, standard, and experimental counts were all of 60 min. duration. The potassium-40 intensity was computed from the difference between the potassium-sugar phantom and background ratio to the difference between the background and each subject, and reported in grams of potassium. The sensitivity of the system was approximately 10 counts/hr/g of potassium.

Standard techniques for measurement of body widths and circumferences were utilized (Hertzberg, *et al.*, 1963). Isometric strength tests of legs and arms were measured with cable tension apparatus after Clarke and Clarke (1963). At the end of the experiment, residual lung volume was measured only once by the modified closed-circuit oxygen rebreathing system of Rahn (1954).[13]

Experimental Environment

A segment of one wing of the Cowell Health Center, University of California, Davis, was contracted for use in one of the pilot experiments and during the 27 day summer experiment. The portion of the wing used consisted of two wards with a two bed capacity each, and a larger ward across the hall (see Figure 2.5). The two smaller wards were interconnected by a preparation room. The smaller wards housed the subjects during bed rest, and most experimental tests were completed there. Renal function and exercise tests were completed in the larger ward, which was shared with a collateral NASA project investigating circulatory (venous flow) debilatation, under the direction of Loren Carlson.[14] The hospital was air conditioned and the measured ambient temperature varied only $\mp$ 1°C.

The hospital kitchen staff prepared the meals under the supervision of one of the senior investigators. Meals were served in the hospital staff dining room during pre-bed rest periods, and were brought to the subjects in bed during the bed rest period. The ambulatory external control subjects (numbers 10 and 12) continued to eat in the dining room during the bed rest period.

The subjects were supervised 24 hours a day by the hospital nursing staff, and the investigators were on call 24 hours a day and handled all routine experimental procedures.

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[12]Measurements made by Dr. Marvin Goldman, AEC Research Station, Radiobiology Division, University of California, Davis.

[13]Measurements taken by Dr. Jack Wilmore, Department of Physical Education, University of California, Berkeley.

[14]Dr. Loren Carlson, School of Medicine, University of California, Davis; NASA Contract NGR 05-004-026.

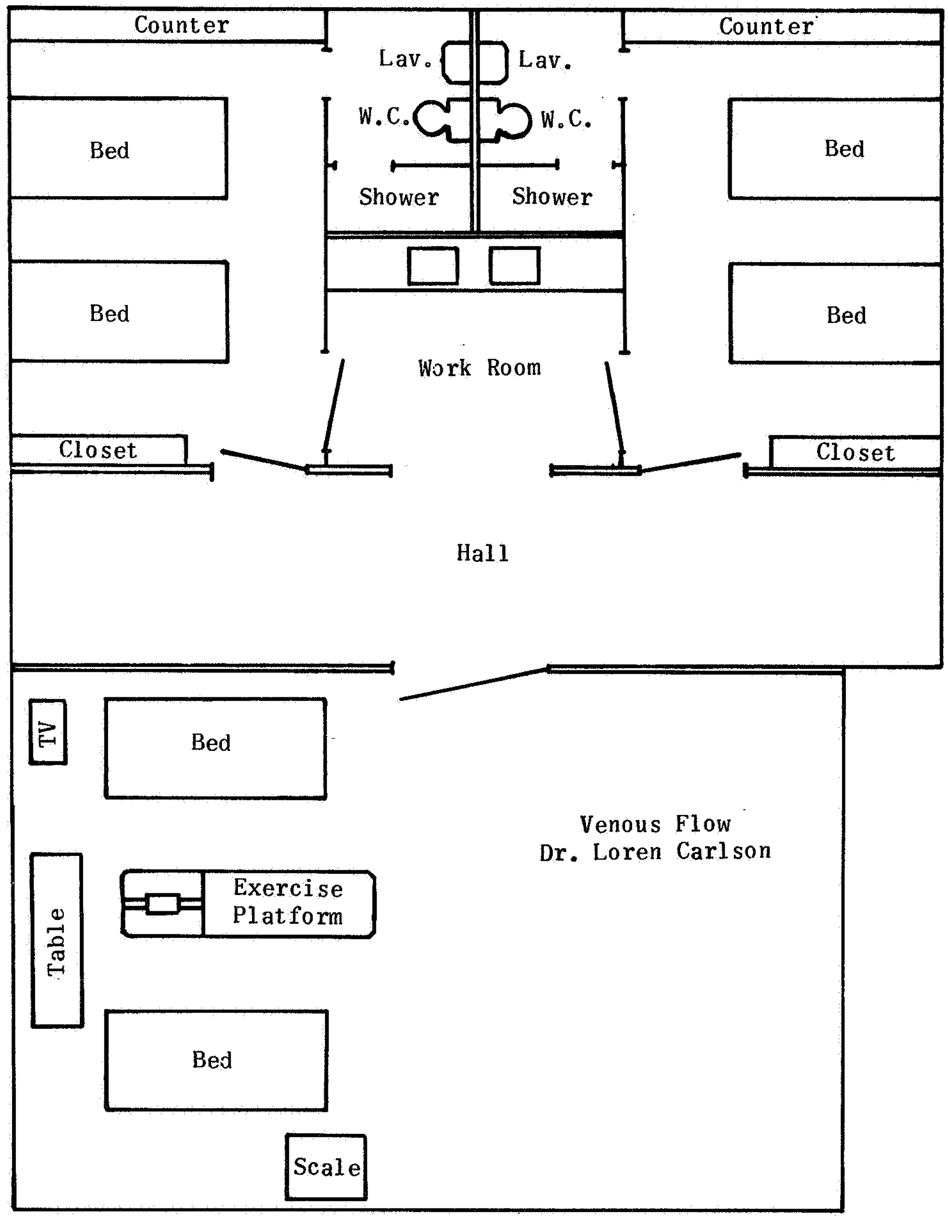

FIG. 2.5. ILLUSTRATION OF HOSPITAL FLOOR PLAN. The area used for experimental testing and for confinement of the eight subjects during bed rest was made available by the University Student Health Center, University of California, Davis campus. Two subjects occupied each of the two smaller rooms during bed rest. The larger room across the hall was used for exercise procedures.

During isotope administration and renal function tests, one of two hospital staff physicians attended the subjects for the duration of the experiment.

Subjects had access to music and television, and films were scheduled on two occasions. Prism glasses were available to facilitate reading in the recumbent position. Subjects were allowed visitors at regular hospital hours. No attempt was made to restrict movement beyond that of maintaining the horizontal position.

Subject Descriptions

The subjects were all University undergraduate students, between 18-21 years of age. They were selected on the basis of availability, maturity, interest and desire to cooperate. All resided in Davis during the experiment, except one who was living in Sacramento with his parents (subject 5). A description of the subjects follows. The subjects were assigned priority in the experiment on the basis of personal evaluation, ease of urinating in the recumbent position, and availability for experimental protocol. The highest priority subjects were placed in the exercise group. The second highest priority subjects were placed in the internal control group. These two groups were paid the same stipend. The lowest priority subjects were placed in the external control group and were paid one half the stipend of the others, since their commitment involved one half the renal function tests and did not require the nine days of bed rest. Basic

Subject	Age	Height (cm)	Weight (kg)	BSA (m2)	%Body Fat	LBM (kg)	Max $\dot{V}O_2$ (L)	Knee Ext. Strgth. (lbs)
Exercisers								
1	19.3	174.0	81.7	1.98	13.6	70.6	3.850	200
3	20.5	167.6	63.4	1.71	14.0	54.6	3.075	130
5	19.3	176.5	70.2	1.85	17.6	57.8	3.064	190
7	21.1	186.2	70.4	1.93	8.6	64.3	3.960	190
Group $\bar{x}$	20.0	176.1	71.4	1.86	13.5	61.8	3.487	178
Controls								
2	19.2	175.3	69.8	1.84	15.7	58.9	2.859	140
4	19.9	172.7	69.7	1.82	18.0	57.1	2.910	140
6	19.0	172.0	60.2	1.70	7.4	55.7	3.326	157
8	19.2	173.5	80.9	1.96	15.0	68.8	3.200	210
Group $\bar{x}$	19.3	173.4	70.2	1.83	14.4	60.1	3.074	162

TABLE 2.2. BASIC CHARACTERISTICS OF SUBJECTS. All data shown here were collected prior to the beginning of the 27 day experiment (BSA=body surface area; LBM=lean body mass as determined by water immersion).

characteristics of the subjects are given in Table 2.2. The investigators' observations of individual subjects is outlined below:

1. A sophomore with athletic inclinations. Well muscled, with large frame, and in excellent physical condition, since he lifted weights and ran regularly. He did not smoke. He possessed a mild and "easy going" nature, but became impatient with experimental procedures due to several misunderstandings of experimental dates. He was considered to be reliable and was assumed to have closely followed the experimental protocol during the ambulatory periods when he was away from the experimental area. In order to maintain his state of physical condition, he was allowed to lift weights for 30 minutes each day and run one mile per day during the ambulatory periods. His only mistake during the experiment was the loss of some of his urine on day 10, making this day's 24 hour pool unusable. He could urinate easily in the recumbent position.

2. A freshman with athletic inclinations. Fairly well muscled with average frame, but he was not involved in a physical fitness program during the experiment. He played football during his freshman year on the university freshman team. He did not smoke. He was interested in the experiment, but manifested some irritability as the experiment progressed due to a complex schedule which occasionally interfered with his personal plans. He was considered to be impeccably reliable and was assumed to follow experimental protocol away from the hospital. The only subject engaged in strenuous activities, he worked as a laborer in heavy construction work in the hot sun for several hours a day. This caused his state of hydration to fluctuate greatly. His water ration on the first days was inadequate, which added to his irritability. He vomited on the last day of the equilibration period. He was one of the two subjects who could not urinate easily during bed rest, and frequently voided more than ½ liter per urination.

3. A junior with athletic inclinations. Average muscle mass, small frame, and in good physical condition. He played vigorous recreational basketball quite regularly prior to the experiment. He did not smoke. He possessed a mild temperament and was exceptionally cooperative. He was of impeccable reliability, always well informed and followed directions explicitly. He was assumed to have adhered to the experimental protocol at all times. He performed light work, indoors, before the bed rest period. There were no unusual events in his performance or responsibilities. He could urinate easily in the recumbent position.

4. A sophomore with no athletic inclinations. Average muscle mass, of medium frame and in average physical condition. He did not smoke. He became irritable occasionally when a tense situation arose, but was otherwise cooperative. His reliability was slightly questionable, as on one day he failed to record urine volumes, and on another day his water balance records indicated the possibility of the ingestion of fluids which were not recorded. Otherwise, it was thought he was of sufficiently high enough ethical character to be depended on to follow the experimental protocol while not under direct observation. He was several times found with his knees slightly raised in bed, and when reminded to keep his body in a horizontal position, he did so begrudgingly. On the fifth renal function test he had a "temper tantrum" and refused to continue because one of the assistants accidentally spilled a few drops of water on him. He did not move from the recumbent position during this episode and after persuasion he continued. He frequently developed headaches during the placement of the intravenous catheter. He vomited once during bed rest. He did not work and spent most of the day indoors during the ambulatory period. He had difficulty in voiding during bed rest, but not as much as subject 2.

5. A freshman with no athletic inclinations. Of average muscle mass and frame, this subject was not actively engaged in a physical exercise program. He did not smoke. He was mild tempered, cooperative and of impeccable reliability and always followed directions. He was assumed to have adhered to experimental protocol at all times. He performed light work, indoors, before and after bed rest. There were no unusual incidents in his behavior or responsibilities throughout the experiment. He voided with ease in the recumbent position.

6. A freshman with no athletic inclinations. Of light muscular development and small frame, this subject did not actively engage in sports. He smoked three cigarettes per day. He was occasionally temperamental and complained of pain during the catheter placement. He was of impeccable reliability and was assumed to have adhered to his responsibilities during the ambulatory periods. He did not work and stayed indoors most of the time during the ambulatory period. There were no unusual events in his behavior. He voided with ease during bed rest.

7. A senior with athletic inclinations. Of tall, slender frame and thinly muscled, this subject was in good physical condition, although he participated in no organized fitness program at the time of the experiment. However, the previous year he had participated on the University cross country team. He did not smoke. Of mild temperament, this subject became slightly uncooperative towards the end of the experiment, and questioned the necessity of certain experimental procedures, such as the ingestion of approximately 0.5 gms of sodium chloride that remained in his daily electrolyte supplement. He had experienced six months in a bi-valve body cast eight years previous to the experiment, and hence was fairly adaptable to the discomforts of bed rest. He was of impeccable reliability and was assumed to have adhered to experimental protocol at all times. He did not work during the ambulatory periods and stayed indoors most of the time. He voided with ease in the recumbent position.

8. A sophomore with slight athletic inclinations. Well muscled and of large frame, he normally engaged only in recreational sports, although he had been a high school football player. He was cooperative and mild tempered, and always well informed of his responsibilities. He was of impeccable reliability. He worked as a life guard during the ambulatory periods and stayed in the shade most of the time. He developed mild hemorrhoids during bed rest, but never complained of the discomforts of the experiment. He voided with ease during recumbency.

10. A sophomore with no athletic inclinations. Medium muscle mass and frame. He was in below average physical condition. He did not smoke. He was mild tempered, but appeared to have difficulty in self-discipline, particularly in following directions and experimental protocol. He also tended to argue excessively about the importance of procedures, and was extremely sloppy in specimen handling. His errors consisted of walking across the hall before a basal metabolism, spilling his sample of D_2O midway through its ingestion, and spilling a portion of his urine samples approximately once each day. He found it necessary to defecate during one of the renal function tests, and required absolute privacy and silence in order to void during these tests. During the experiment, he verbally expressed disbelief in the validity of science. Unfortunately, these feelings were never alluded to during interviews before the experiment. His records indicated discrepancies in fluid intake when water balance was calculated. He remained indoors during most of the experiment. He had difficulty in voiding in the recumbent position.

12. A sophomore of non-athletic inclinations. Medium muscle mass and frame. He was in average physical condition. He smoked three cigarettes per day. He was mild tempered, cooperative and reliable to the best of his ability. During the experiment, he frequently either ignored instructions or forgot committments. He was rarely helpful in instances of noted discrepancies, for which he was occasionally the cause. He did, however, attempt to satisfy the requirements of the experiment, and expressed the desire to gain a sense of discipline from participating in this experiment. During two of three renal function tests he found it necessary to defecate, and once appeared dizzy and faint at which time his pulse rate, blood pressure, and pupillary reflexes were normal. He had difficulty in voiding in the recumbent position during renal function tests, in spite of the fact that he manifested no such difficulty in preliminary tests. Unlike number 10, he did not argue the validity of the experiment and cooperated to the best of his ability.

The third and fourth sub-groups (subjects 5, 6, 7, 8, and 12) proved to be more cooperative and malleable than the first two sub-groups. However, they had the advantage of observing the earlier sub-groups complete the full experiment. Since they were allowed to observe the first two sub-groups on occasion, and were forewarned of typical mistakes, there was less question of what was expected of them with regard to the experiment protocol. They were decidedly more effective subjects. It should be stated that subjects numbers 1, 2, 3, and 4 had participated in the pilot experiments, and had already submitted to extensive testing prior to the beginning of the 27 day master experiment.

With the exception of subject number 1, the exercise subjects expressed a mild dislike for exercise, and said they would have preferred to be the non-exercise controls. This was an unexpected response, since the investigators thought the twice daily exercise bout would serve to break the monotony of the continuous bed rest.

All subjects looked forward to the end of bed rest with great anticipation. At the end of bed rest, two subjects (number 2 and 6) complained of dizziness upon standing initially. (However, none of the subjects developed orthostatic syncope during brief tilt table tests, conducted prior to their return to an erect posture at the end of bed rest.) Subject number 6 complained of dysmetria and mild uncoordination for two days, maintaining that he could not hit a billiard ball or judge distance. Other subjects had no symptoms other than mild and transitory weakness.

The low residue diet was well received except that most subjects (those not living at home) complained of the large bulk and the regimented three meals a day. They claimed that they usually skipped breakfast and ate a lighter dinner; hence, a full meal at those times was unusual for them. During renal test days, breakfast was eaten late and very close to lunch; this telescoping of meals was especially objectionable. The ambulatory controls (subjects 10 and 12), who ate the same three day dietary cycle for 19 days (bed rest subjects were given a reduced and slightly different diet when bed rest began), complained mildly of the monotony of the diet near the 15th or 16th day. All subjects expressed their eagerness to return to their normal eating habits.

Defecation and urination in the recumbent position presented special problems for some subjects. One subject (number 7) disliked the idea of horizontal defecation to the extent of not defecating once during the bed rest period. Subjects numbers 2 and 4 had problems in horizontal urination, especially number 2, who once could not urinate until approximately 850 ml of urine had collected in his bladder. However neither presented a great problem during renal function tests.

The subjects generally remained in good spirits throughout bed rest, and there were no personal conflicts apparent among any of them. During bed rest, mobile beds facilitated occasional change of roommates. All developed a closer friendship following termination of the experiment.

Appendix I: *Pilot Experiment on Water Exchange with a Single Subject*

A ten day experiment was designed to investigate problems associated with the diuresis of recumbency, and to compare the water exchange of a single subject while in a normal and in a hypohydrated state of water balance. Water exchange was measured both in an erect and recumbent posture, and with respect to rest and exercise, in both states of hydration. The subject was maintained on a strict liquid intake and food diet of known water content. Urine output was measured throughout the entire experiment, and water balance was estimated for each of the ten days. The subject's state of hydration was investigated with respect to the effect of hypohydration on a diuresis produced by a water load, and the effect on a diuresis during exercise. It is known that prolonged recumbency causes loss of water from the body by a self limiting diuresis, resulting in hypohydration (McCally and Lawton, 1963). In this pilot experiment, 12-15 hours of recumbency served to slightly hypohydrate the subject. The extent to which hydration could be reduced by recumbency was examined by continuous bed rest each day with only 6-8 hours in the upright posture. The nature of the later 27 day master experiment was such that it required a thorough practical knowledge of the effects of hypohydration on gross body water exchange, since not only water allowances had to be maintained to suit a subject's needs, but, in addition, the measurement of renal function required the repeated collection of urine samples at short intervals during the renal clearance tests. Further the volume of water loading required to satisfy a continuing urine production essential to renal clearance tests, had to be sufficiently small to avoid excessive natriuresis which allegedly accompanies a recumbent diuresis (McCally and Lawton, 1963; Surtshin and White, 1956; Thomas, 1957). The complication of natriuresis can trigger a change in body fluid exchange. Pilot Experiment I was designed, therefore, to investigate a suitable method for promoting a diuresis that would serve the purposes of the master experiment, but which would alter the normal processes of physiology to the least extent.

Methods and Procedures

Hypohydration was produced by reduction of fluids and by prolonged recumbency prior to the day of the experiment. Exercise consisted of 30 minute bouts at 600 Kpm on a bicycle ergometer in the upright position. The total experiment consisted of morning and afternoon experimental periods, during which water loads of various volumes were followed by a period of urine collection with or without a bout of exercise (see Table 2.3). Two days of dietary equilibration preceded the experiment. Eight control diuresis periods were run on random days spaced throughout the experiment. The periods differed in the time of day, the volume of the distilled water load, the posture of the subject and his state of hydration. Recumbent diuresis trials were intentionally interrupted by the subject assuming an erect posture. The effect of an interruption of a recumbent diuresis, e.g., by the subject standing upright, was compared with an upright diuresis interrupted by exercise. Four exercise experiments were run and differed with respect to the time of the day and the volume of water load drunk before exercise commenced. The subject was normally hydrated in the morning exercise, and on different days was hypohydrated for the afternoon exercise. Gross water balance was calculated by input (food and liquid total water content) subtracted from output (urine). It is expressed as minus or plus milliliters of water per 24 hour period. Therefore, the term water balance is essentially a misnomer, as insensible water loss, active perspiration and fecal weight changes were not calculated; however, it is used in preference to more cumbersome terms such as water input-output exchange, or the like.

Results

In erect control diuresis trials, the urine rates were effected by state of hydration, but in recumbent trials, the rates were altered only by the volume of the water load irrespective of state of hydration. The assumption was made that assuming an erect posture in the middle of a recumbent diuresis inhibited the diuresis, but did not prevent it. It was found that the longer the subject was recumbent, the sharper was the decline of urine flow when he stood up. One liter of water was found to support a diuresis in excess of 2 ml/min. for approximately one hour, in all conditions, which was adequate for the aims of the master experiment (see Figure 2.6). A 45 minute latent period preceded the diuresis

Day	Hydration	Experiment	Time	Water Load
1	Normal	Control basal		
2	Normal	Control basal		
3	Normal	Inhibition of diuresis during exercise	Morning	1 liter
4	Normal	Inhibition of diuresis during exercise	Morning	½ liter
5	Normal	Control upright diuresis	Morning	1 liter
5	Normal	Control upright diuresis (discarded)	Afternoon	½ liter
6	Reduced	Control recumbent (recumbency interrupted before water load)	Afternoon	1 liter
7	Reduced	Inhibition of diuresis during exercise	Afternoon	1 liter
8	Reduced	Inhibition of diuresis during exercise	Afternoon	½ liter
9	Normal	Control upright diuresis	Morning	½ liter
9	Normal	Control upright diuresis (preceded by short recumbency)	Afternoon	½ liter
10	Normal	Control recumbent diuresis	Morning	½ liter
10	Normal	Control recumbent diuresis	Afternoon	1 liter
10	Normal	Control upright diuresis (preceded by recumbency)	Afternoon	½ liter

TABLE 2.3. EXPERIMENTAL DESIGN FOR PILOT I. The experiment was designed to investigate the character of a diuresis produced by ingesting 1 or ½ liter of water at different times of the day. The inhibition of urine flow during exercise, the amount of time necessary for production and length of the diuresis, and the effects of hypohydration were the variables studied.

in the erect position and a 30 minute latent period preceded the recumbent diuresis. The latent period was found to be reproducible within ten minutes irrespective of the state of hydration. The use of either exercise or standing to interrupt recumbency caused a depression of urine flow within fifteen minutes. The duration of the diuresis when interrupted by exercise was between two and three hours with one liter, compared to one hour duration or less with one-half liter (see Figure 2.6). In recumbent trials without exercise the amount of water excreted was larger than the amount consumed, whereas this effect was not observed in trials in the erect posture. This response was recognized as the source of a possible problem in the interference with hydration in bed rest. The persistance of a negative water balance (up to several days) was found to be directly related to the duration of recumbency based on 24 hour periods (see Figure 2.7). Water balance stabilized after several days, and was no longer reduced except by restrictions of fluids. This is in accordance with the theory that the diuresis of recumbency is self limiting once the body reaches a minimum state of hydration (see Figure 2.7).

Conclusions

The generally accepted diurnal variation of response to a diuresis produced by water loads, as reported by Barclay et al. (1947) was not evident in our case study, but, instead, the state of hydration was found to have the strongest influence on the diuresis, irrespective of the time of day. This was particularly true when the effects of exercise and posture were eliminated. A water load of one liter or more was found to satisfy the requirements of the summer master project, in which renal studies will last from two to three hours. As recumbency is prolonged, there is a correspondingly larger inhibition of urine flow rate when an erect posture is assumed. It is anticipated that exercise in the recumbent position will produce the same effect. A water load must be designed with two objectives in mind: (1) to produce adequate urine flow for fifteen minute urine collections, and (2) to continue the diuresis during and following exercise in subjects undergoing prolonged bed rest.

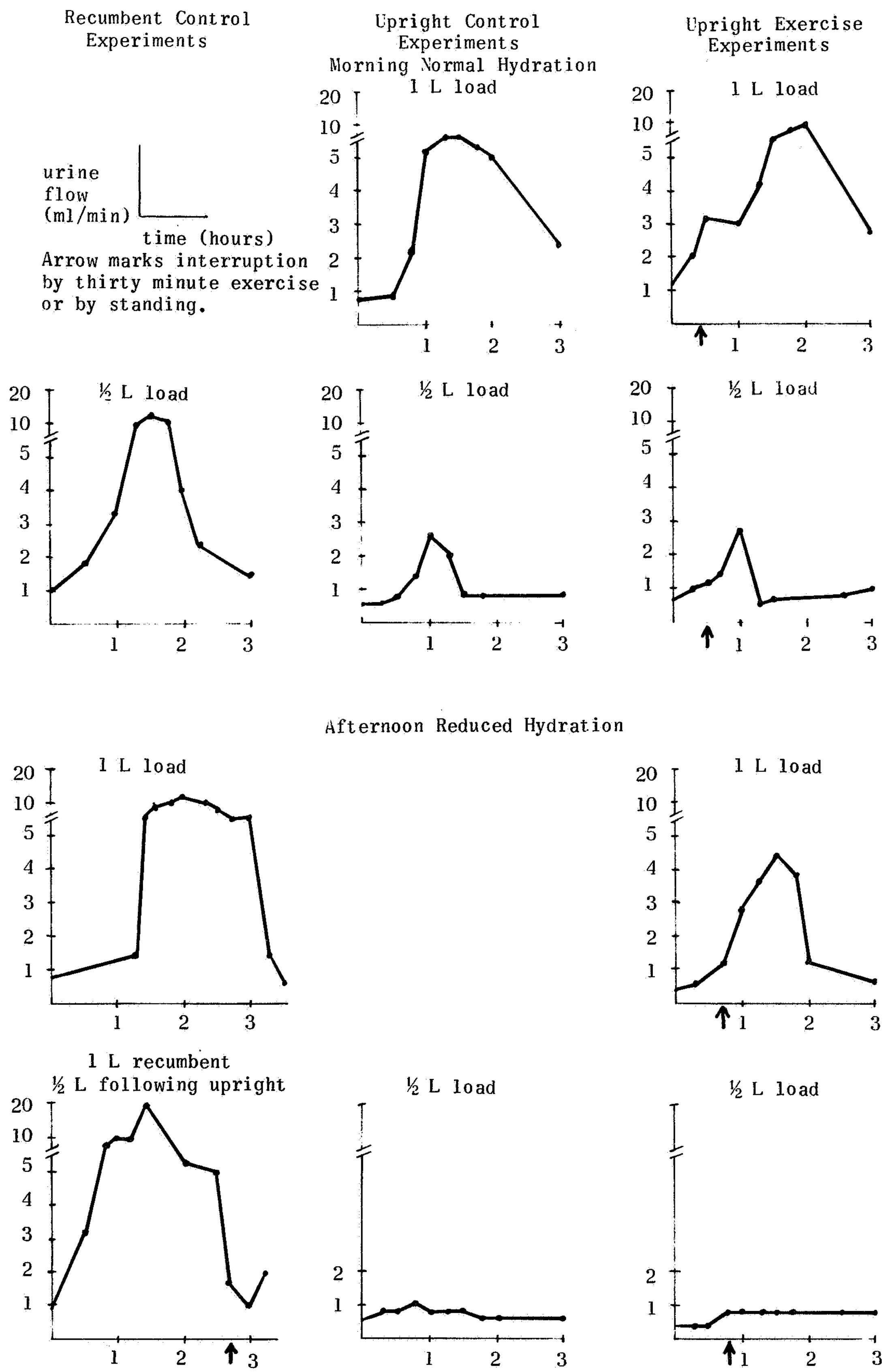

FIG. 2.6. DIURESIS PRODUCED BY TWO VOLUMES OF WATER LOADS. Three trials, labled "Recumbent Control," "Upright Control," and "Upright Exercise" were conducted in the morning (upper half of page) and afternoon (lower half) with a one half liter or one liter distilled water load. Legend appears in upper left.

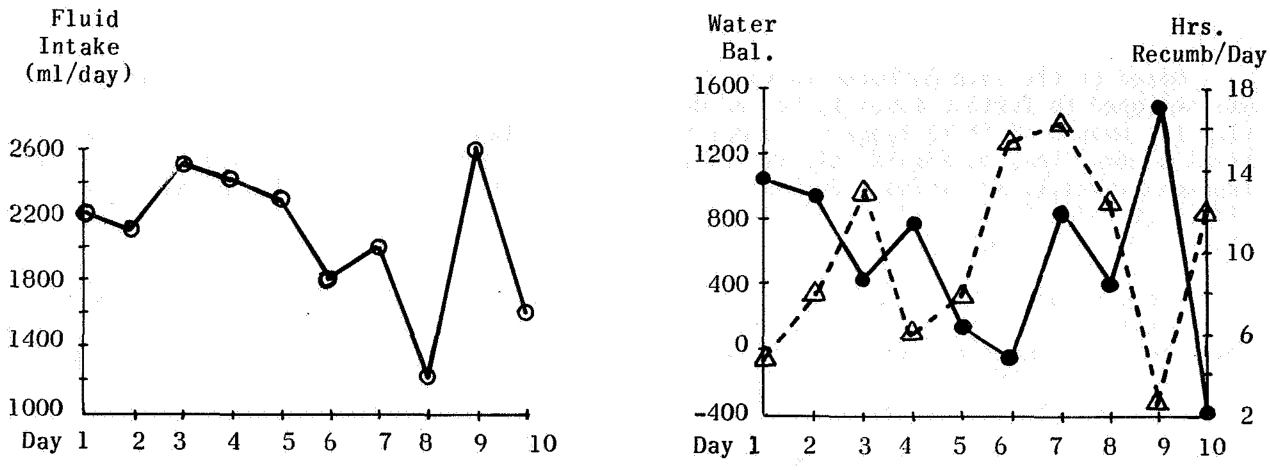

FIG. 2.7. PILOT I. EFFECT OF RECUMBENCY ON THE HYDRATION OF A SINGLE SUBJECT. A single subject on a diet of known water content remained recumbent for 2-15 hours per day. Water balance was determined by input-output, and extra renal routes of water excretion were assumed to be constant (fluid intake, water balance, hours recumbent/day).

Appendix II: Pilot Experiment for Renal Function Tests

Based on the data gathered in the first pilot experiment, a second pilot experiment was designed to further investigate the physiological characteristics of water balance viz.,the amount of fluid required to maintain water balance, the regulation of electrolytes, renal plasma flow, glomerular filtration rate and urine production by the kidney during an induced diuresis, involving recumbent, resting, and exercise periods. In addition, the effect of reduced hydration (hypohydration) on the renal functions detailed above were also studied.

The subsequent 27 day master experiment was envisioned to include a controlled state of hydration, including daily monitoring of the intake of fluids and daily calculation of water balance. However, the measurement of renal function requires an artificially induced diuresis, either by pharmacologic diuretics, and/or large volumes of water. A method of water loading was sought that would induce a sufficient urine flow for collection of urine samples, yet would alter water balance and the related electrolytes minimally. The procedures of water loading were progressively refined with respect to minimum volume and length of diuresis and an optimum was determined to accomodate the renal tests designed for the subsequent master bed rest experiment.

Experimental Protocol

An experimental protocol was also sought for renal function tests that would adequately measure renal plasma flow and glomerular filtration rate in the resting, exercise, and in a post exercise state. The requirements demanded of the test protocol were two fold: (1) that the test be short enough to avoid excessive water loading, and (2) to sustain a urine flow in excess of 2 ml/min. throughout the test.

One-half to one and one-half hours has been most frequently suggested in the literature as the length of time necessary for equilibration of the infusion chemicals, para amino hippurate and inulin (Smith, 1956 and Reubi, 1963). The minimum time needed for equilibration for our experimental protocol, which included exercise, was sought. Preliminary testing to determine individual work loads and the duration of exercise were conducted to establish exercise schedules for the subjects in the subsequent master bed rest experiment.

All of the planned procedures were tested and solutions for problems, such as micturation and complete voiding of the bladder in the recumbent position, transporting, exercising and weighing of subjects confined to recumbency, were finalized. All new equipment and analytical procedures were calibrated and validated, respectively.

Experimental Design

Pilot II consisted of five serial experiments, involving seven of the ten subjects screened for the master experiment. Four subjects participated in the first four experiments, one of whom was replaced by a fifth subject on the last weekend. The other two subjects participated in the fifth experiment, which consisted of the revised and finalized procedure for renal function tests during recumbent exercise.

Experimental Procedures

All subjects served as their own controls for a 24 hour record of fluid and food intake and urine output before each weekend experiment. They recorded diet, urine volume and physical activity for the Fridays preceding the weekend, and during the following Saturday and Sunday, on standard forms. During the first three weekends, two subjects were placed on a diet with a reduced water content, i.e., were hypohydrated for those experiments. Each experiment is detailed in the Pilot II experimental design shown in Table 2.4.

Diuresis trials lasted for three to four hours and included 15 minute clearance periods. Distilled water loads systematically varied from 800 ml to 1300 ml (as indicated in Figure 2.8) were used. The volume of the water load was corrected with the subject's lean body mass (using 62.5 kg as a standard value) in order to allot a commensurate degree

Weekend	Experiment	Purpose
1	Upright Control	Diuresis produced in upright position with different loads of water and in different states of hydration. Electrolyte excretion measured.
2	Recumbent Exercise	Interruption of recumbent diuresis with exercise, different loads of water and varying states of hydration. Electrolyte excretion measured. Creatinine clearances measured.
3	Erect-Recumbent Renal Function	Measure of renal plasma flow as affected by posture; experimental techniques and procedures for renal function tests.
4	Recumbent Exercise with Renal Test	Measure of renal plasma flow as affected by exercise; testing procedure during exercise.
5	Final Revised Recumbent Exercise	Complete infusion and exercise tests in finalized protocol.

TABLE 2.4 PILOT II EXPERIMENTAL DESIGN. Five weekend experiments were designed to investigate various procedures of the master experiment, viz.,recumbent exercise on an ergometer, urination and complete voiding of the bladder, and response to various water loads. In addition, a format for a renal function test to be performed on six occasions by all subjects was designed and tested for practicability.

of water load to each subject irrespective of size. Sodium, potassium and chloride were measured in pre-diuresis, diuresis and post-diuresis urines in the first two experiments, which served to standardize the experimental water load volumes and to investigate urinary electrolyte excretion.

In the third experiment, renal plasma flow was measured in both the upright and recumbent positions to obtain a control reference for technique and procedure for the renal function tests. After the priming dose was administered, a Sage constant infusion pump was used to sustain blood levels of para amino hippurate (PAH) (see Appendix III). The concentration of priming and sustaining infusate was calculated on the basis of lean body mass, rather than the more conventional use of body surface area for this standardization. The concentration of original infusion dose was based on the observations of Reubi (1963), but following the initial trials, was found to be too high in young subjects and hence, was subsequently reduced. Blood was withdrawn from an indwelling 18 gauge 1½ inch Gelco (Rochester) catheter.

Seven 15 minute clearance periods were conducted in the fourth and fifth experiments, which served to finalize the renal function test protocol. Blood was drawn every 15 minutes to follow PAH concentration during the equilibration period, and to determine the earliest time at which the blood PAH level was stable. The subjects were asked to urinate in the recumbent position, but, if they could not, they were allowed to stand for three clearances only, viz.,preceding exercise, after exercise, and at the termination of the infusion. Under the latter circumstances, the remaining four scheduled urinations were omitted.

Prior to the second experiment, which was designed to assess the effect of recumbent exercise on a diuresis, the first five subjects were exercised in the sitting position on a Monark bicycle ergometer at a fixed load of 750 Kpm for five minutes. Heart rate, pulmonary ventilation and oxygen consumption were measured during the ride. The heart rate was also monitored during the subsequent five minute recovery. Based on the exercise and recovery heart rates, a level of 1050 or 1200 Kpm was selected for a second five minute ride. The data analysis made it quite clear that the 750 Kpm load was submaximal for all subjects, and could be continued for an extended period of time without diminished performance, while the heavier loads brought the subjects above steady-state values. Consequently, the minimum horizontal exercise load was set at 750 Kpm for recumbent exercise. The length of exercise in the second and fourth experiment was 15 minutes, but was extended to 30 minutes in the fifth experiment. During these experiments, a standard Collins ergometer (electrically braked), modified for use in horizontal exercise, and supported on a custom made metal adjustable frame, was used. During exercise, the subjects were placed on a training table with shoulder braces for support, which prevented their sliding backwards while peddling. The subjects were weighed before and after exercise, and transported in the recumbent position on a portable Fairbanks-Morse mobile in-bed scale with hydraulic lift.

Results

Conclusions based on Pilot I were confirmed, i.e., the water load found to be most effective was 800 ml (corrected for lean body mass) and taken 30 to 45 minutes before the diuresis, with a second load of 500 ml taken immediately before exercise. The diuresis that resulted was approximately two and one-half hours in duration, and ended rather abruptly (see Figure 2.8). The hypohydrated states caused urine flow rate to be reduced, but did not delay the onset of diuresis or alter the observed time pattern. Therefore,

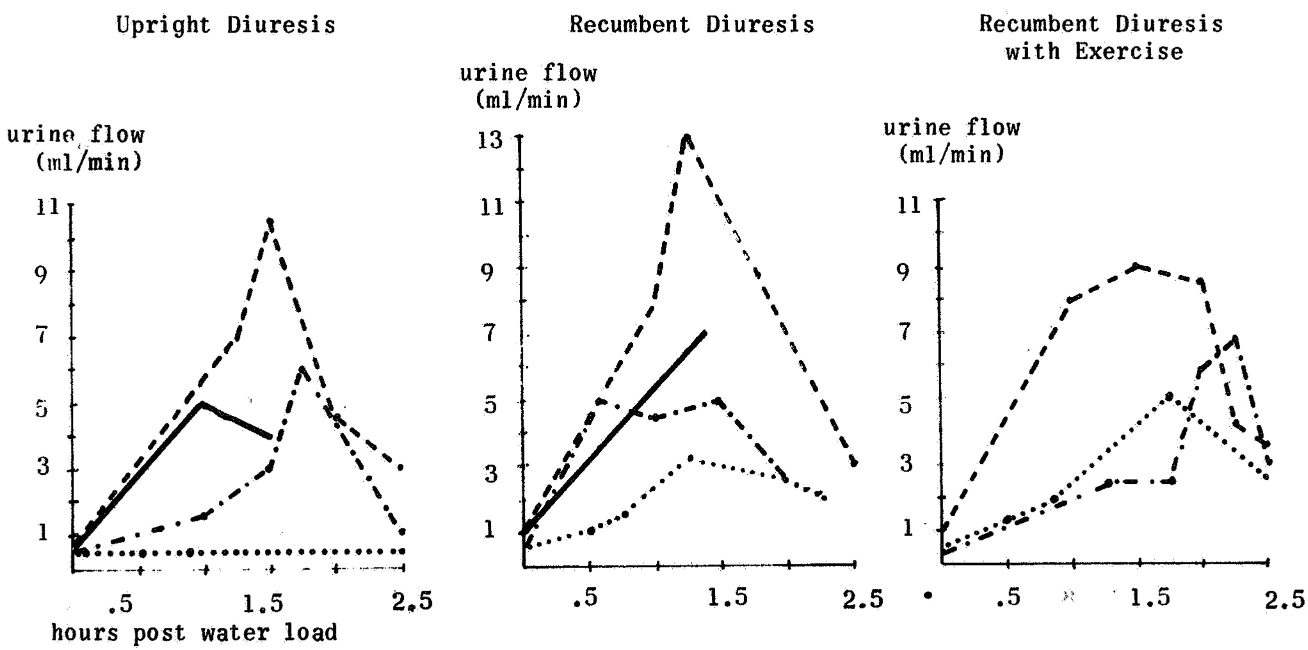

FIG. 2.8. PILOT II. AVERAGE URINE FLOW OF SIX SUBJECTS FOLLOWING THE INGESTION OF 1 OR ½ LITER OF WATER. A diuresis was produced by ingesting water loads in various conditions. Two subjects in each experiment were in a state of reduced hydration produced by restriction of fluids for one day (normal hydration with 800 ml water load ——— , normal hydration with 1300 ml water load - - - -, hypohydrated with 800 ml water load ······ , hypohydrated with 1300 ml water load -·-·-).

the anticipated reduction of hydration in bed rest would not necessitate any alteration of protocol. Sodium loss was found to be greatest in the first half-hour (excess of 100 mEq/liter) and decreased from 50 to 90 percent in the subsequent measurement periods encompassing two hours. This is in general agreement with the findings of other authors (Rosenbaum *et al.*, 1953; Hulet and Smith, 1961).

It was observed that the subjects who were capable of emptying their bladders in the erect position, also consistently voided completely in the recumbent position. One subject who, upon occasion, did not completely void in the erect posture, also had incomplete micturations several times in the recumbent experiments. Two subjects who had difficulty in voiding on a 15 minute schedule in the upright experiments, subsequently were found to be unable to void within that schedule in the recumbent experiments. A number of approaches were tried to stimulate micturation, but all proved unsuccessful.

The use of lean body mass as a basis for calculating infusate concentrations yielded fairly consistent blood concentrations of PAH within 0.5 mg% in all subjects (who varied in body weight from 58 Kg to 82 Kg). The concentrations were found to stabilize in 15 minutes, considerably shorter than the equilibration times observed by Smith (1956) and Reubi (1963).

Renal plasma flow decreased by 10 to 40 percent when the subjects changed from a recumbent to an erect posture. A less variable drop of 30 to 40 percent of RPF was observed following either 15 or 30 minutes of exercise at a work load of 750 Kpm. Endogenous creatinine clearances were constant within 10 ml/min. at this load. These findings are in agreement with the observations of Grimby (1965).

The work load of 750 Kpm was well tolerated by all but the smallest subject (body weight of 58 Kg), who complained of leg fatigue midway through one of the exercise tests. In all subjects, heart rates, pulmonary ventilation and oxygen intake rose to submaximal levels within five minutes and remained essentially the same for the duration of the horizontal ride. The heart rates varied from 100-140 beats/min among the five subjects, indicating that the larger, stronger subjects might well tolerate higher loads for extended periods of time. Since the heart rates and oxygen intake leveled off at submaximal values, it was clear that a longer exercise bout at, or near, this load was possible for these subjects.

Conclusions

The final renal function testing procedure can be limited to a 15 minute equilibration period, followed by two 15 minute pre-exercise resting clearances. A 30 minute bout of exercise best satisfies the aims of the master experiment; hence, a 30 minute exercise during infusion will follow the pre-exercise clearances. Because recovery from exercise was rarely complete after 30 minutes post-exercise, the post-exercise clearances should be of 15 minutes duration, followed by one of 30 minutes, making a total time of two hours.

With the data available, water balance can be calculated for each subject during the first few days of the equilibration period, and sufficient water will be supplemented in the diet the following days to replace 24 hour insensible water loss, active perspiration water loss, and urine loss as measured during the first days of equilibration. The bed rest water allowance will be altered to replace the water loss by those same routes. Water allowances will be altered only on days of infusion when an extra 1300 ml will be added to the diet.

Those subjects who were not able to void frequently will serve as control subjects, since only two clearances are required on each infusion during bed rest, and will serve as a measure in changes of RPF and GFR in the non-exercising bed rest controls.

All subjects who did not participate in the pilot experiment will undergo preliminary diuresis trials for the purpose of detection of incomplete bladder voiding, and for practice of micturating in the recumbent position.

Appendix III: Experimental Protocol for Renal Function Tests and Exercise Metabolism

On days 10, 12, 15, 19, 21, and 27, a standard battery of tests was run from 0700 to 1230. To minimize the physician's time, the testing battery for each subject was initiated 15 to 45 minutes apart. The intervals were also spaced to allow the use of two infusion pumps and one exercise apparatus by as many as four subjects. The first subject was awakened at 0600, and a basal metabolism was run (see sample form entitled "Infusion: Instructions for First Exerciser".) Following the metabolism test, the subject was transferred to a mobile surgical guerney and transported to the experimental room. His morning urine was collected, body weight recorded, and he was given 800 ml of distilled water to drink by 0715.[1] The physician arrived at 0715 and the necessary injections and infusion equipment were prepared. The equipment, chemical agents, and supplies were then laid out in order of their use. At 0730, the physician placed the indwelling catheter and withdrew approximately 21 ml of blood (this sample provided the serum blanks for I-131, T_2O, PAH, and inulin), and then closed the catheter with a stylet. Following the placement of the indwelling catheter, the physician inserted a 20 gauge, 1 inch needle into the opposite arm, injected the I-131 and flushed it at least twice. A timer was started immediately after the initial injection. The syringe barrel was removed with the needle left in the arm, and was replaced by the T_2O syringe (the subject elevated his arm to prevent back flow of blood). After the T_2O was injected, the primer syringe with the extension tubing attached was inserted and the PAH and inulin solutions were injected. The syringe was then refilled with the sustaining infusate by an I.V. saline bottle (with premixed inulin and PAH) with an extension tube, and the syringe then placed in the pump and the sustaining infusion initiated. An I-131 blood sample was drawn from the catheter ten minutes later. Thirty minutes later the renal infusion test was begun with the infusion PAH-inulin now in equilibrium in the blood, and with any pain precipitated by the catheter placement now subsided. The subject voided his bladder and a clock was started. Two clearances later (each of 15 minutes, with a blood sample drawn from the catheter at the midpoint of the period, i.e., at 8 min. and at 23 min.) exercise was begun. The subject was placed on the exercise table several minutes in advance of the exercise bout, drank 500 ml distilled water, urinated for the second pre-exercise clearance, and immediately began to exercise with the respiratory apparatus in place. He exercised for 30 minutes with gas samples collected at 10 minute intervals throughout the exercise bout. The subject immediately urinated at the end of exercise and was transferred again to his bed. At 15 minutes post-exercise and at 45 minutes post-exercise, he completed two more clearances. T_2O blood samples were taken from the catheter at 2, 3, and 4 hour post injection intervals.

Because of the many procedural complications during the renal function tests, such as occasional clotted catheters, inability to urinate on schedule, etc., a system was finalized with three major objectives: 1) in the event of a delay, to proceed with the test as designed without interrupting the proper intervals, 2) to insure that a fixed schedule was followed with respect to the entire experiment, ie., with respect to multiple subject use of the exercise apparatus and infusion pumps within a single morning, and 3) to insure that the actual time (more or less than the scheduled time, e.g., 15 minutes for a pre-exercise clearance) was known.

Three clock time notations were routinely employed (refer to sample instruction forms numbers 1 and 2). The subject clock time refers to the timer started at the beginning of the experiment; it was turned off whenever there was a delay past the scheduled time, permitting the subsequent tests to proceed on the established time interval. The tentative clock time was used only as a reference, to insure that later subjects would not have to wait for the exercise apparatus, or the infusion pump. It should be re-emphasized that the intricacy of the timing was extremely critical, since exact water loads were calculated very carefully (see Appendices I and II) to produce a diuresis of desired duration, with an established lag phase prior to the onset of diuresis. Hence, any delay in the procedure

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[1]The amount of water consumed was 800 ml x $\frac{\text{LBM of subject}}{62.5\text{ Kg}}$. All administered substances were corrected by this formula, using 62.5 Kg as the constant for the average LBM.

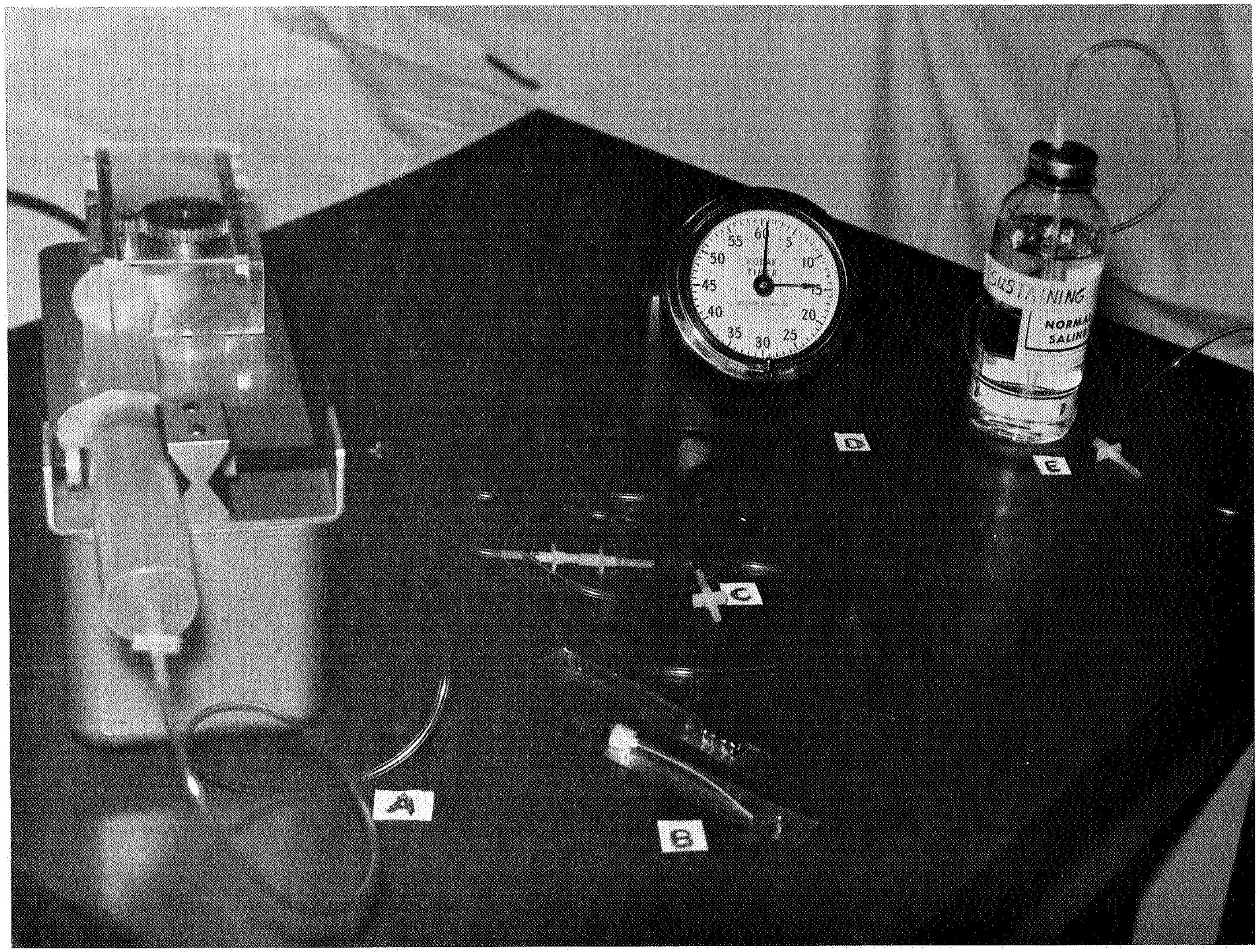

FIG. 2.9. APPARATUS FOR RENAL FUNCTION TESTS. The tests began with the insertion of an 18 guage Gelco catheter (B) 30 minutes or more before the first clearance. A 20 guage one inch needle was placed in a vein of the opposite arm. A priming solution was administered (see FIG. 2.10) from a 50 ml syringe through an extension tube (C) connected to the needle. The syringe was disconnected from the extension tube and was refilled with the sustaining infusion fluid (E). The extension tube was reconnected and the infusate was delivered intravenously at the rate of 1.64 ml/min by a Sage pump (A). Intervals during the tests were timed with a Kodak timer (D).

could cause the subject to "run dry" of urine and greatly complicate if not obviate the accurate determination of renal function. Inherent errors in non-catherized urine collection necessitated sufficiently large volumes to avoid this problem, and therefore the optimal urine flow which was designed to last 2½ hours had to last the duration of the test. The experimental clock time was the elapsed time recorded between clearances and procedures, irrespective of delays. It was recorded as each sample was collected. The samples following the collection were taken to a central collection room (directly across the hall) and given to a technician, who recorded the time of collection (as a double check), the name of the subject, the volume of the sample, and aliquoted the sample into previously prepared vials and tubes for subsequent laboratory analyses. An example of the form used for recording this data is included (see form number 3).

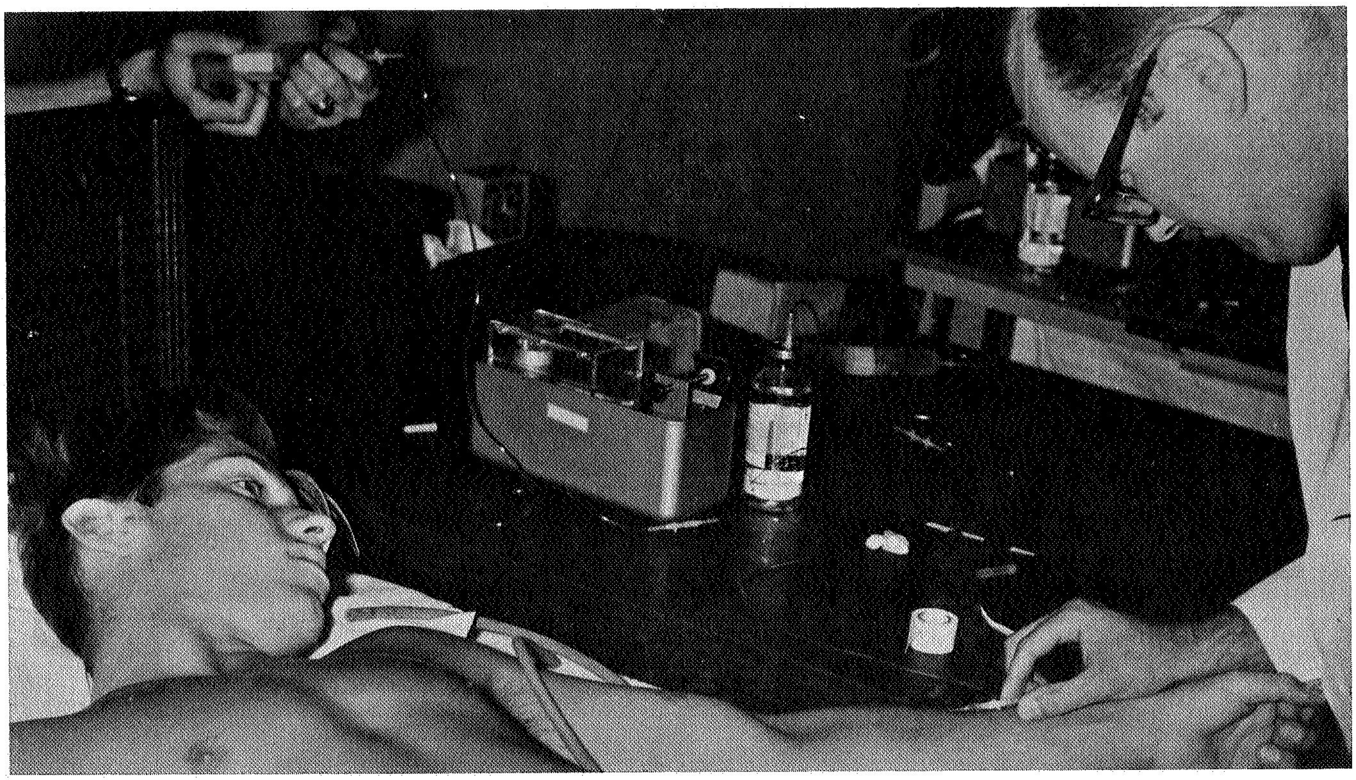

FIG. 2.10. INJECTION OF THE PRIMING DOSE OF PARA AMINO HIPPURATE AND INULIN. A 20 guage needle was inserted in the left arm and the priming solution was infused from a 50 ml syringe (upper left). After the syringe was emptied, it was refilled by attaching the extention tube to an I.V. saline bottle containing the sustaining solution (next to infusion pump).

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Infusion: Instructions for First Exerciser

Form Number 1

Subject Clock	Tent. Time	Expt'l Clock	
	6:15		Basal metabolism, basal urine specimen and weight.
	6:35		Begin water load - drink slowly.
	6:40		(Push bed into venous flow room, nearest to the door, for two or three exercisers.)
	7:05		Take urine blank for renal function, set clock at 35.
	7:15		Insert Rochester catheter, withdraw blank for I-131, renal function - 21 ml.
35	7:20		Inject I-131, T_2O, turn on clock, followed by inulin, PAH primer, followed by infusion.
45	7:30		Withdraw I-131 sample with heparinized syringe - 9 ml.
(1)15	8:00		Void bladder, equilibration urine - turn off clock and set at 15 - do not start clock until urine is obtained.
(1)22	8:07		Pre Ex I plasma - 5 ml.
(1)30	8:15		Pre Ex I urine - after urine, place subject on scale, in prone position.
(1)37	8:22		Pre Ex II plasma - 5 ml.
(1)40	8:25		Weigh subject, then give second part of water - drink fast.
(1)45	8:30		Pre Ex II urine - turn off clock, set at 45, start clock after urine is obtained and when exercise has begun.
(2)00	8:50		Exercise plasma - 5 ml.
(2)15	9:05		Exercise ends, turn off clock, place subject on scale, urinate - term exercise. Start clock when subject urinates. Take weight after subject urinates, remove from scale after weight.
(2)22	9:12		Post Ex I plasma and serum and first T_2O - 15 ml.
(2)30	9:20		Post Ex I urine
(2)45	9:35		Post Ex II plasma - 5 ml.
(3)00	9:50		Post Ex II urine - do not turn off pump until get urine. (Afterwards remove subject from room and return to opposite ward of third exerciser - for three exercisers.)
	10:12		Second T_2O plasma - 3 ml.

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Infusion: Instructions for Second Exerciser

Form Number 2

Subject Clock	Tent. Time	Expt'l Clock	
	7:00		Basal metabolism, basal urine specimen and weight.
	7:40		Begin water load - drink slowly.
	7:50		Push bed into venous flow room, farthest from the door.
	8:15		Take urine blank for renal function, set clock at 35.
	8:25		Insert Rochester, withdraw blank for I-131, renal function - 21 ml.
35	8:30		Inject I-131, T_2O, start clock, followed by infusion primer, followed by sustaining infusion pump.
45	8:40		Withdraw I-131 sample with heparinized syringe - 9 ml.
(1)15	9:10		Equilibration urine - turn off clock and set at 15 - start clock after urine is obtained.
(1)22	9:17		Pre Ex I plasma - 5 ml.
(1)30	9:25		Pre Ex I urine, after urine place subject on scale, in prone position.
(1)37	9:32		Pre Ex II plasma - 5 ml., afterwards get weight of subject, then begin second water load - drink fast.
(1)45	9:40		Pre Ex II urine - turn off clock and set at 45, immediately after urine place on exercise stand, begin exercise and start clock.
(2)00	10:00		Exercise plasma - 5 ml.
(2)15	10:15		Exercise ends - turn off clock, place subject on scale, collect urine (term exercise) and turn on clock after urine. Get weight next. Remove from scale.
(2)22	10:22		Post Ex I plasma, serum and first T_2O plasma - 15 ml.
(2)30	10:30		Post Ex I urine.
(2)45	10:45		Post Ex II plasma
(3)00	11:00		Post Ex II urine - do not turn off pump until urine is collected.
	11:22		Second T_2O plasma - 3 ml.

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Renal Function and Exercise

Form Number 3

Name____________________
Subject #_______________
Exp't day_______________
Date____________________

Wt before exer._________
Exp't time______________
Wt after exer.__________
Exp't time______________

	Volume	Subject Time
Water Drank:	Slo-300	(0) 20
	500	(1) 0
	500	(2) 30
	Period	Subject Time
Respiratory Gas:	Basal	(0) 0 - (0) 20
	Exercise	(2) 45 - (3) 15

URINE

Tentative Time	Expt'l Time	Subject Clock	Label	Volume	Rate	Notes
		(2) 0	Blank			
		(2) 15	Equil			No Lab Analysis
		(2) 30	Pre Exer I			
		(2) 45	Pre Exer II			
		(3) 15	Term Exer			
		(3) 30	Post Exer I			
		(4) 0	Post Exer II			

BLOOD

Tentative Time	Expt'l Time	Subject Clock	Label	Volume Drawn	Volume Measure	Notes
		(2) 0	Blank	12 ml		5 ml P; 7 ml S; Htc
		(2) 22	Pre Exer I	5 ml		
		(2) 37	Pre Exer II	5 ml		
		(3) 0	Exercise	5 ml		
		(3) 22	Post Exer I	12 ml		5 ml P; 7 ml S; Htc
		(3) 45	Post Exer II	5 ml		

HEMATOCRIT

Blank: (1)__________ Post Exer: (1)__________

(2)__________ (2)__________

Ave.__________ Ave.__________

Appendix IV: Calculation of PAH and Inulin Dosages

The infusion pump used with a 50 ml syringe had a constant rate of 1.64 ml/min. The PAH used was a 20% suspension, while the inulin used was a 10% suspension in normal (0.85%) saline solution. The dosage of each was calculated as the mls of suspension to be infused per minute. Hence, the maximum length of time of the test was estimated, and this time multiplied times the dosage per minute. For example:

length of time for infusion is 165 minutes;
standard dose of PAH is 0.0727 ml 20% PAH/min of infusion time;
standard dose of inulin is 0.333 ml 10% inulin/min of infusion time.

Hence, in this example, the total volume required is 12 ml PAH and 55 ml inulin, respectively. These two volumes were further corrected for the subject's lean body mass. A standard of 62.5 kg was assumed to represent the lean body weight of an average young man. Thus, if the subject's LBM was 68.4, then the total dosage was 12 ml PAH x 68.4/62.5 = 13.2 ml. Likewise, the corrected dosage of inulin would be 60.5 ml. If the pump infuses at a speed of 1.64 ml/min, then the total volume infused would be 1.64 ml/min x 165 minutes = 271 ml infusate. This infusate consisted of 13.2 ml PAH and 60.5 ml inulin, and diluted by 197.3 ml of normal sterile saline. This mixture, referred to as the sustaining infusate, followed the priming dose which was given at the beginning of the experiment to raise blood levels to the proper concentration. The priming dose for young adults was found to be 3 ml PAH and 30 ml inulin. As in the example above, this was corrected for LBM and yielded values 3.28 ml PAH and 32.8 ml inulin for a 68.4 kg man.

Using these dosages, equilibration of the blood levels occurred within 15 minutes and, with one exception of a local burning sensation when only PAH was used, no untoward effect was experienced. This single exception in the pilot work was avoided subsequently by adhering to one of the following procedures: (1) if only PAH is used, it is necessary to dilute 1:15 to prevent perivascular damage if any extravasation should occur during injection, and (2) if inulin is also used, it will dilute the toxicity of PAH and no local pain will be encountered upon injection of the priming dose.

Appendix V: Calculation of Water Balance by Modified Peters-Passmore and Standard Peters-Passmore Equations

If one considers the Peters-Passmore equation mathematically (Consolazio, Johnson, and Pecora, 1963), it can be shown to reduce to only weight changes due to water loss or gain. All other parts of the equation are inserted to correct for food weight that is not digested and metabolized, weight lost by heat or conversion during metabolism of food, and weight retained by addition of the food to body mass. In other words, the equation reduces to:

$$(\text{weight}_2 + \text{metabolic loses}) - (\text{weight}_1 + \text{metabolic gains}) = \text{water balance}$$

Using the concept of water mass-weight gain or loss, one can reduce certain parts of the equation to facilitate a less controlled and less accurate measurement of water balance. In our experiment, the main constituent of concern was insensible water loss and active perspiration, since all other parameters were measured. The primary discrepancy in the calculations are the metabolic gains and losses, e.g., if fat is gained or muscle mass is lost, the weights will be inaccurate if one attempts to measure water mass irrespective of tissue changes. On a daily basis this error is insignificant, but over a longer period, if the change in body composition is great, the error, of course, becomes very large. In this experiment, however, the fat changes were measured by density, and the muscle mass was determined indirectly by several measurements, hence the water balance calculated by the above method could be corrected for non-water tissue mass changes. The modified Peters-Passmore equation is given below and reduced to show that water balance = weight change (water mass weight change).

water input	=	fluid ingested (beverage, or food + water) or infused intravenously
water output	=	urine + sweat + vomitus + blood + fecal water (fecal water was too small to be significant)
EWL (24-hr)	=	fluid input - (urine + 24 hr weight change)
weight change (24-hr)	=	$(\text{weight}_2 - \text{weight}_1)$ + fecal weight
active perspiration	=	weight pre-exercise - weight post-exercise
night IWL	=	weight_1(p.m.) - weight_2(a.m.) + urine(a.m.) (subjects urinated prior to a.m. weight)
day IWL	=	24-hr sweat - (active perspiration + night IWL)

Equation for Water Balance:

WB	=	water gain - water loss
WB	=	water input - (urine + 24-hr sweat)
WB	=	water input - (urine + [fluid - (urine + weight change)])
		or
WB	=	fluid - urine - (fluid - urine - weight change)
WB	=	(fluid - urine) - (fluid - urine) + weight change
WB	=	weight change

Note that sweat or evaporative water loss (EWL) includes insensible water loss (IWL) + active perspiration.

Appendix VI: Determination of Total Body Water by T_2O (Dilution Principle)

A pre-injection reference blood sample was obtained. Following this, a known volume of T_2O, determined by syringe weight pre- and post-injection, was injected intravenously and flushed. Plasma samples were withdrawn at 2, 3, and 4 hour intervals post-injection; from which an aliquot of 3-4 ml of heparinized blood was withdrawn. The time and volume of samples was recorded on a form (see form number 4). This sample was separated into plasma and packed cells, the plasma drawn off, and treated with trichloracetic acid for deporteinization. Protein was filtered out, and the filtrate was frozen for subsequent analysis.

Because the plasma also had high levels of I-131 (small beta, large gamma emitter) which would interfere with T_2O measurement (beta emitter) the samples were stored for five months to allow the I-131 to decay below the level of interference (I-131, half-life is 8 days, T_2O half-life is 31 years).

The determination consisted of measuring 1 ml of stock sample of T_2O (purchased in the same lot as that used for the experiment), added to 125 ml plasma diluted 40,000 times (or approximately the dilution of 1 ml of T_2O in the plasma), and using this as a standard. The standard was prepared at the same time of the sample determination, and prepared identically to the preparation of the sample.

The following equation was used for total body water calculation:

$$\frac{\text{concentration of injected } T_2O \text{ (cpm) x volume } T_2O \text{ injected}}{\text{concentration of plasma } T_2O \text{ (cpm)}} = \text{Total Body Water}$$

The concentration of T_2O injected was uniformly 2 millicurie per ml.

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Form Number 4

Tritium (T_2O) Procedure

Name____________________ No.____________________
Date____________________
Experimental Day________ Time____________________

The tritium is injected immediately following the injection of I-131. This is done through the infusion needle on experimental days 10, 19, and 27.

The syringe with the stock sterile solution, approximately 2 mc in 1 ml is weighed gravimetrically before and after injection.

1 ml plasma specimens are deproteinized with 10% TCA. (1 ml plasma in 2 ml, 10% TCA.)

PROCEDURE

		Weight	Time	Volume
1.	Weigh syringe with T_2O	_____._____gms		
2.	Inject 1 ml (approximately 2 mc/ml) and flush		______	______ml
3.	Weigh syringe - T_2O	_____._____gms		
4.	Draw first blood specimen 2 hrs. post-injection		______	______ml
5.	Draw second blood specimen 3 hrs. post-injection		______	______ml
6.	Draw third blood specimen 4 hrs. post-injection		______	______ml

7. Blood is handled as described above. The deproteinized plasma is heat sealed in a 2 ml vial. Store in freezer.

CALCULATIONS

1. Total dose = U E k/λ

   Where U = Mc Tritium injected / 9 body weight

   E = Average energy / disintegration in e v (average beta energy = E_{max}/ 3)

   λ = Biodecay constant (0.693 / $T\frac{1}{2}$)

   k = $(3.7 \times 10^7)\ (1.6 \times 10^{-12})$ / 100

2. Total Body Water =

LABEL CODE

Specimens	Label Format
Blank	#. Jones (No. 1)
2 Hr.	Plasma T_2O (Blank)
3 Hr.	7-3-67 (Equilib.)
4 Hr.	

Appendix VII: Determination of Blood Volume by RISA (Dilution Principle)

A standard dose syringe of RISA water, containing 2 ml and between 1 and 2 microcurie, was placed in the well chamber of an automatic radiation counter (Volumometer) and an initial count made. A pre-injection reference blood sample was drawn and the RISA was then injected intravenously and the syringe thoroughly flushed with blood. A sample was drawn from the opposite arm within 10-15 minutes. The site of injection was scanned with a geiger counter to check perivascular leakage. The blood samples and the empty syringe were then measured in the well chamber within three hours. The Volumometer compares the empty syringe with the total count of the full syringe, calculates net count and reads the correct volume. Plasma was determined by difference from PCV measured on blood samples obtained from the same aliquot. The following formula was used:

$$\text{Plasma volume} = BV \times 1 - (9.927 \times \text{peripheral Htc})$$

where BV is the blood volume measured directly by the Volumometer and 0.927 is the ratio of total body hematocrit (Htc) to peripheral hematocrit.

Appendix VIII: Individual Diets for Pre-Bed Rest and Bed Rest Periods

Diets were classified according to the subject's weight by standard procedures outlined earlier. The following terminology was used to designate each classification: 60 kg, 70 kg, and 80 kg included subjects who had a body weight within the range of 60-70, 70-80, or 80-90 kg, respectively. The final decision for the classification of subjects with border line weights was based upon their lean body weight as determined previous to the experiment. The subject dietary assignments are delineated in Table 2.5. The pre-bed rest diets are referred to as "regular", the bed rest diets as either "exercise" or "no-exercise". The external ambulatory controls continued the "regular" diet for both the pre-bed rest and bed rest periods. Each dietary regimen was based on a three day cycle, designated as Day I, II, and III.

Sodium and potassium content are listed in the diet. In addition to this, a supplemental ration was added to bring the total sodium and potassium intake to a constant amount for each of the three days of the cycle. The dietary chloride content was estimated from values given by Mattice (1950). The sum of the supplemental and dietary content of these electrolytes, together with an itemization of dietary sources of electrolytes as allotted in the subjects' meals, is detailed in Table 2.6.

Subject	1	2	3	4	5	6	7	8	10	12
Dietary Classification	80 kg	70 kg	60 kg	70 kg	70 kg	60 kg	70 kg	80 kg	70 kg	70 kg
Experimental Classification	Ex	N-Ex	Ex	N-Ex	Ex	N-Ex	Ex	N-Ex	Am	Am

TABLE 2.5. SUBJECTS' DIETARY ASSIGNMENTS BASED ON WEIGHT AND RECUMBENT ACTIVITY. During the first 10 days of the experiment (equilibration), diets were based only on the subjects' weight. When the bed rest period began, changes in diets were made according to the subjects' activity, i.e., exercise or non exercise (Ex = exercise, N-Ex = non exercise, Am = ambulatory).

Dietary Classification	Electrolyte Input/Day					
	Na gms	(mEq)	K gms	(mEq)	Cl gms	(mEq)
Regular 60, 70, 80 kg	6.50	(286)	4.76	(126)	10.1	(290)
Exercise 60 kg	5.19	(226)	3.77	(96)	7.30	(206)
Exercise 70 kg	5.27	(234)	3.90	(100)	7.52	(212)
Exercise 80 kg	5.46	(238)	3.94	(101)	7.66	(216)
No Exercise 60 kg	4.33	(188)	3.15	(81)	5.14	(145)
No Exercise 70 kg	4.55	(198)	3.22	(82)	5.35	(151)
No Exercise 80 kg	4.56	(199)	3.38	(87)	5.46	(154)

TABLE 2.6. DIETARY INPUT OF ELECTROLYTES. All subjects received the same input during the equilibration or pre-bed rest period. Allowances were reduced according to estimated requirements. Allowances are above recommended daily electrolyte requirements (Weisberg, 1962) in order to assure adequate input.

DIET: Day I, Regular

Food	60 kg				70 kg				80 kg			
	Quantity	Na+	K+	Cal.	Quantity	Na+	K+	Cal.	Quantity	Na+	K+	Cal.
BREAKFAST												
Eggs - Hard cooked	2 med.	118	124	154	3 med.	177	186	231	3 med.	177	186	231
Grapefruit Juice - Frozen, unsweetened	1 C	2	373	96	1 C	2	373	96	1 C	2	373	96
Sugared Puff Wheat	1 sm box	39	24	96	1 sm box	39	24	96	1 sm box	39	24	96
Toast - White enriched bread	1 slice	116	24	63	2 slices	233	48	126	2 slices	233	48	126
Butter	4 pats	197	5	146	4 pats	197	5	146	4 pats	197	5	146
Jelly - No jam	2 Tb	7	30	100	2 Tb	7	30	100	2 Tb	7	30	100
LUNCH												
Spaghetti - Cooked, enriched	1 C	2	91	218	1 C	2	91	218	1C	2	91	218
Tomato Sauce with Hamburger	1/2 C	1139	660	128	1/2 C	1139	660	128	1/2 C	1139	660	128
French Bread - No garlic	2 pieces	232	36	108	2 pieces	232	36	108	2 pieces	232	36	108
Parmesan Cheese	2 T	105	22	55	2 T	105	22	55	2 T	105	22	55
Butter	4 pats	197	5	146	4 pats	197	5	146	4 pats	197	5	146
Jello	1 C	121	---	160	1 C	121	---	160	1 C	121	---	160
Apple Juice	3/4 C	7	185	100	3/4 C	7	185	100	1 C	9	248	133
Oreo Cookie	---	---	---	---	1	55	4	57	2	109	8	114
DINNER												
Tomato Soup - Diluted	1/3 can	784	186	73	1/3 can	784	186	73	1/3 can	784	186	73
Roast beef		120	740	470		120	740	470		120	740	470
Gravy - No salt	4 Tb	---	---	164	4 Tb	---	---	164	4 Tb	---	---	164
Noodles	1 C	3	70	107	1 C	3	70	107	1 C	3	70	107
Cottage Cheese	1/3 C	218	67	71	1/2 C	326	100	107	1 C	672	200	214
Bread - White enriched	---	---	---	---	1 slice	116	24	63	1 slice	116	24	63
Butter	4 pats	99	2	73	4 pats	99	2	73	4 pats	99	2	73
Pudding - Butterscotch	1/2 C	91	193	207	1/2 C	91	193	207	1/2 C	91	193	207
Orange Juice	1 C	37	465	100	1 C	37	465	100	1 C	37	465	100
NIGHT SNACK												
Lemonade	1 C	Trace	38	107	1 C	Trace	38	107	1 C	Trace	38	107
Spice Cake or Oreo Cookie	1 Cookie	55	4	57	1 sm piece	122	53	210	1 lg piece	244	106	400
		3689	3344	2999		4211	3540	3448		4735	3760	3835

DIET: Day II, Regular

Food	60 kg Quantity	60 kg Na+	60 kg K+	60 kg Cal.	70 kg Quantity	70 kg Na+	70 kg K+	70 kg Cal.	80 kg Quantity	80 kg Na+	80 kg K+	80 kg Cal.
BREAKFAST												
French Toast - Norm. amt. milk & egg, no salt	2 pieces	26	52	250	3 pieces	38	78	375	3 pieces	38	78	375
Bacon - Pork	2 strips	167	38	98	3 strips	250	56	147	4 strips	333	74	196
Orange Juice - Frozen, unsweetened	1 C	4	465	110	1 C	4	465	110	1 1/2 C	6	697	165
Butter	2 pats	99	2	73	4 sm pats	197	5	146	4 sm pats	197	5	146
Syrup	4 T	54	3	229	5 T	68	4	286	5 T	68	4	286
LUNCH												
Broiled Beef Cutlet	1 pattie	46	448	235	1 pattie	46	448	235	1 pattie	46	448	235
Tomato Juice	3/4 C	366	408	37	3/4 C	366	408	37	3/4 C	366	408	37
Deviled Eggs - No salt	2 halves	167	96	125	2 halves	167	96	125	4 halves	334	192	250
Saltines	4 squares	141	15	56	4 squares	141	15	56	4 squares	141	15	56
Custard - Vanilla	4 from 1 pt milk	124	229	205	4 from 1 pt milk	124	229	205	4 from 1 pt milk	124	229	205
Gingerale - Coke	---	---	---	---	8 oz	35	7	106	8 oz	35	7	106
DINNER												
Beef Noodle Soup - Diluted	1/3 can	756	63	58	1/3 can	756	63	58	1/3 can	756	63	58
Broiled chicken - Small broiler	1/2 sm	172	704	334	1/2 sm	172	704	334	1/2 sm	172	704	334
Rice	1 C	1	72	201	1 C	1	72	201	1 C	1	72	201
Tomato Juice	3/4 C	366	408	37	3/4 C	366	408	37	3/4 C	366	408	37
Cottage Cheese	1/2 C	326	100	107	1/2 C	326	100	107	1/2 C	326	100	107
White Rolls	1	192	36	114	1	192	36	114	2	384	72	228
Chocolate Cake	---	262	130	339	---	262	130	339	---	262	130	339
Butter	4 pats	197	5	146	4 pats	197	5	146	6 pats	296	7	219
NIGHT SNACK												
Root Beer	8 oz	35	7	100	8 oz	35	7	100	8 oz	35	7	100
Vanilla Ice Cream	1/2 C	36	80	150	2/3 C	36	80	193	2/3 C	36	80	193
		3537	3361	3004		3779	3416	3457		4322	3800	3873

DIET: Day III, Regular

Food	60 kg				70 kg				80 kg			
	Quantity	Na+	K+	Cal.	Quantity	Na+	K+	Cal.	Quantity	Na+	K+	Cal.
BREAKFAST												
Scrambled Eggs - Plus milk, no salt	3 med	370	210	231	3 med	370	210	231	4	496	280	308
Bacon	3 strips	250	56	147	3 strips	250	56	147	3 strips	250	56	147
Toast - White enriched	2 slices	233	48	126	2 slices	233	48	126	3 slices	345	72	189
Butter	4 pats	197	5	145	4 pats	197	5	146	6 pats	295	7	219
Jelly	1 Tb	4	15	50	2 Tb	7	30	100	3 Tb	10	45	150
Apple Juice	6 oz	7	185	92	6 oz	7	185	92	6 oz	7	185	92
LUNCH												
Frankfurters	2	1084	217	248	2	1084	217	248	2	1034	217	248
Buns	1	215	45	115	2	430	89	230	2	430	89	230
Cottage Cheese	1/2 C	326	100	107	1/2 C	326	100	107	1 C	652	200	214
Lemonade	1 C	Trace	30	104	1 C	Trace	30	104	1 C	Trace	30	104
Ice Cream Bar - Covered with chocolate	---	28	52	162	---	28	52	162	---	28	52	162
Mustard	4 Tb	260	26	20	4 Tb	260	26	20	4 Tb	260	26	20
DINNER												
Chicken or Turkey Noodle Soup - Diluted	1/3 can	823	63	58	1/3 can	823	63	58	1/3 can	823	63	58
Broiled Lamb Chop	7 oz	140	824	680	7 oz	140	824	680	7 oz	140	824	680
Fine Rye Bread	1 slice	136	37	57	1 slice	136	37	57	1 slice	136	37	57
Rice	1 C	1	72	201	1 C	1	72	201	1 C	1	72	201
Tomato Juice	3/4 C	366	408	37	3/4 C	366	408	37	3/4 C	366	408	37
Ice Cream - Vanilla	1/2 C	41	75	145	1 C	82	151	290	1 C	82	151	290
Butter	4 pats	197	5	146	4 pats	197	5	146	4 pats	197	5	146
NIGHT SNACK												
Orange Juice - Frozen, unsweetened	3/4 C	3	348	82	3/4 C	3	348	82	1 C	4	465	110
Oreo Cookie	---	---	---	---	3	168	13	180	3	168	13	180
		4681	2821	2954		5108	2969	3444		5774	3297	3842

DIET: Day I, Exercise

Food	60 kg				70 kg				80 kg			
	Quantity	Na+	K+	Cal.	Quantity	Na+	K+	Cal.	Quantity	Na+	K+	Cal.
BREAKFAST												
Omelet	2 eggs	118	124	154	3 eggs	117	186	231	3 eggs	177	186	231
Cheese	---	---	---	---	2 T	12	14	56	2 T	12	14	56
Orange Juice	1 C	37	465	100	1 C	37	465	100	1 1/2 C	56	697	150
Toast	1 slice	116	24	63	1 slice	116	24	63	2 slices	233	48	126
Butter	1 pat	49	1	36	1 pat	49	1	36	2 pats	98	2	72
Jelly	---	---	---	---	---	---	---	---	1 T	4	15	59
LUNCH												
Chicken Broth	1 C	374	62	11	1 C	374	62	11	1 C	374	62	11
Chicken Piece	1/4 chick	86	352	167	1/2 chick	172	704	334	1/2 chick	172	704	334
Cottage Cheese	1/2 C	326	100	107	1/2 C	326	100	107	1/2 C	326	100	107
Cranberry Juice	1 C	2	25	160	1 C	2	25	160	1 C	2	25	160
Saltines	4 squares	141	15	56	4 squares	141	15	56	4 squares	141	15	56
Ice Cream	1/2 C	42	123	145	1/2 C	42	123	145	3/4 C	63	184	217
Root Beer	8 oz	2	88	100	8 oz	2	88	100	8 oz	2	88	100
Candy - Hard butterscotch	---	---	---	---	---	---	---	---	5	---	---	105
DINNER												
Chicken with Rice Soup	1 can	867	93	45	1 can	867	93	45	1 can	867	93	45
Veal T-bone	1	130	850	370	1	130	850	370	1	130	850	370
Noodles	2/3 C	2	49	74	1 C	3	70	107	1 C	3	70	107
Gravy	2 T	---	---	82	4 T	---	---	164	4 T	---	---	164
White Bread	1 slice	116	24	63	1 slice	116	24	63	1 slice	116	24	63
Butter	1 pat	50	12	36	1 pat	50	12	36	1 pat	50	12	36
Pudding in Pie Shell	1 piece	307	167	303	1 piece	307	167	303	1 piece	307	167	303
Lemonade	2 C	Trace	64	210	2 C	Trace	64	210	1 C	Trace	32	105
Tomato Juice	---	---	---	---	---	---	---	---	1 C	488	544	50
NIGHT SNACK												
7-up	8 oz	20	2	80	12 oz	27	2	120	12 oz	27	2	120
Sugar Wafer Cookie	2	11	4	32	2	11	4	32	4	22	8	64
		2796	2644	2394		2961	3093	2849		3670	3942	3202

DIET: Day II, Exercise

	60 kg				70 kg				80 kg			
Food	Quantity	Na+	K+	Cal.	Quantity	Na+	K+	Cal.	Quantity	Na+	K+	Cal.
BREAKFAST												
Pancakes	3" dia	423	115	169	4" dia	564	154	225	4" dia	564	154	225
Bacon	2 pieces	167	38	98	2 pieces	167	38	98	4 pieces	334	76	196
Pineapple Juice	1 C	2	375	138	1 C	2	375	138	1 C	2	375	138
Syrup	1 pack	1	10	104	1 pack	1	10	104	1 pack	1	10	104
Butter	1 pat	49	1	36	3 pats	147	3	110	3 pats	147	3	110
LUNCH												
Chicken Noodle Soup	1 can	930	52	59	1 can	930	52	59	1 can	930	52	59
Hamburger - Raw	4 oz	39	458	235	4 oz	39	458	235	4 oz	39	458	235
Buns	1	215	45	115	1	215	45	115	1	215	45	115
Catsup	2 T	455	123	30	2 T	455	123	30	2 T	455	123	30
Lemonade	1 C	Trace	32	105	1 C	Trace	32	105	2 C	Trace	64	210
Custard or Jello	1/2 C jlo	61	---	80	1 C cust	124	229	205	1 C cust	124	229	205
Cottage Cheese	---	---	---	---	---	---	---	---	1/2 C	326	100	107
DINNER												
Tomato Soup	1 can	890	212	82	1 can	890	212	82	1 can	890	212	82
Turkey		164	822	358		164	822	358		164	822	358
Fine Rye Bread	1 slice	136	37	57	1 slice	136	37	57	1 slice	136	37	57
Cottage Cheese	1/2 C	326	100	107	1/2 C	326	100	107	1/2 C	326	100	107
Cranberry Juice	1 C	2	25	162	1 C	2	25	162	1 C	2	25	162
Butter	1 pat	49	1	36	2 pats	99	2	73	2 pats	99	2	73
Sherbert	1 C	10	44	258	1 C	10	44	258	1 C	10	44	258
Apple Juice	---	---	---	---	1 C	10	250	124	1 C	10	250	124
NIGHT SNACK												
Orange Juice	1 1/2 C	56	697	150	1 1/2 C	56	697	150	1 1/2 C	56	697	150
Oreo or Sugar Wafer	2 sugar w	55	4	32	1 Oreo	55	4	57	2 Oreo	110	8	114
		4030	3191	2411		4392	3712	2852		4940	3886	3219

DIET: Day III, Exercise

Food	60 kg				70 kg				80 kg			
	Quantity	Na+	K+	Cal.	Quantity	Na+	K+	Cal.	Quantity	Na+	K+	Cal.
BREAKFAST												
Cream-O-Wheat	sm pack	273	17	107	sm pack	273	17	107	sm pack	273	17	107
Butter	3 pats	147	3	110	4 pats	89	4	146	4 pats	89	4	146
Brown Sugar	1 T	42	48	50	1 T	42	48	50	1 T	42	48	50
Toast	1 slice	116	24	63	1 slice	116	24	63	2 slices	233	48	126
Jelly	1 T	3	15	50	1 T	3	15	50	2 T	6	30	100
Grape Juice	1 C	6	300	160	1 C	6	300	160	1 C	6	300	160
LUNCH												
Beef Broth	1 C	940	135	30	1 C	940	135	30	1 C	940	135	30
Lamb Chops	1	25	233	151	2	49	466	302	2	49	466	302
Cottage Cheese	1/2 C	375	100	107	1/2 C	375	100	107	1/2 C	375	100	107
Toast	1 slice	116	24	63	2 slices	233	48	126	2 slices	233	48	126
Apple Juice	1 1/2 C	15	375	186	1 1/2 C	15	375	186	1 1/2 C	15	375	186
Oreo or Sugar Wafer Cookie	2 sugar w	55	4	32	2 Oreo	107	8	114	2 Oreo	107	8	114
Butter	1 pat	48	1	36	2 pats	100	24	72	2 pats	100	24	72
Jello	---	---	---	---	---	---	---	---	1/2 C	61	---	80
DINNER												
Beef Noodle Soup	1 can	870	73	64	1 can	870	73	64	1 can	870	73	64
Cubed Beef Steak	6 oz	75	462	328	6 oz	75	462	328	6 oz	75	462	328
Rice	1/2 C	1	36	101	1/2 C	1	36	101	1/2 C	1	36	101
White Rolls or Bread	1 slice	116	24	63	1 roll	192	36	114	2 rolls	384	72	228
Butter	3 pats	147	3	110	3 pats	147	3	110	4 pats	196	4	146
Catsup	1 T	227	62	15	1 T	227	62	15	2 T	455	123	30
Tomato Juice	3/4 C	366	408	37	3/4 C	366	408	37	3/4 C	366	408	37
Cup Cake - Chocolate frosting	1	198	69	211	1	198	69	211	1	198	69	211
Lemonade	1 C	Trace	57	160	1 C	Trace	57	160	1 C	Trace	57	160
NIGHT SNACK												
Ice Cream Bar	1	28	52	162	1	28	52	162	1	28	52	162
Cookies	---	---	---	---	2	55	4	32	2	55	4	32
		4189	2525	2396		4507	2826	2847		5157	2963	3205

DIET: Day I, No Exercise

Food	60 kg				70 kg				80 kg			
	Quantity	Na+	K+	Cal.	Quantity	Na+	K+	Cal.	Quantity	Na+	K+	Cal.
BREAKFAST												
Scrambled Eggs	3	177	186	231	3	177	186	231	3	177	186	231
American Cheese	---	---	---	---	---	---	---	---	2 T	12	14	56
Orange Juice	1 C	37	465	100	1 C	37	465	100	1 C	37	465	100
Toast	1 slice	116	24	63	2 slices	233	48	126	2 slices	233	48	126
Butter	1 pat	49	1	36	2 pats	97	2	72	2 pats	97	2	72
LUNCH												
Candy	---	---	---	---	8 pieces	---	---	168	5 pieces	---	---	105
Chicken Broth	1 C	374	62	11	1 C	374	62	11	1 C	374	62	11
Chicken	1/4 chick	86	352	167	1/4 chick	86	352	167	1/4 chick	86	352	167
Cottage Cheese	1/2 C	326	100	107	1/2 C	326	100	107	1/2 C	326	100	107
Cranberry Juice	1 C	2	25	160	---	---	---	---	1 C	2	25	160
Saltines	4 squares	141	15	56	4 squares	141	15	56	4 squares	141	15	56
Jello	1/2 C	61	---	80	---	---	---	---	---	---	---	---
Ice Cream	---	---	---	---	1/2 C	42	123	145	1/2 C	42	123	145
Root Beer	---	---	---	---	8 oz	2	88	100	8 oz	2	88	100
DINNER												
Chicken with Rice Soup	1 can	867	93	45	1 can	867	93	45	1 can	867	93	45
Tomato Juice	---	---	---	---	---	---	---	---	1 C	488	544	50
Veal T-bone	1 steak	130	850	370	1 steak	130	850	370	1 steak	130	850	370
Noodles	1/2 C	2	35	53	1/2 C	2	35	53	1/2 C	2	35	53
Gravy	2 T	---	---	82	2 T	---	---	82	2 T	---	---	82
White Bread	---	---	---	---	1 slice	116	24	63	1 slice	116	24	63
Butter	---	---	---	---	1 pat	50	12	36	1 pat	50	12	36
Pudding	1/2 C	91	193	207	1/2 C	91	193	207	3/4 C	136	288	310
Lemonade	1 C	Trace	64	210	1 C	Trace	64	210	1 C	Trace	64	210
NIGHT SNACK												
Candy	---	---	---	---	---	---	---	---	4 pieces	---	---	84
7-up	---	---	---	---	8 oz	18	1	80	---	---	---	---
Sugar Wafer Cookies	2	11	4	32	2	11	4	32	4	22	8	64
		2470	2469	2010		2800	2717	2461		3340	3398	2803

DIET: Day II, No Exercise

Food	60 kg				70 kg				80 kg			
	Quantity	Na^+	K^+	Cal.	Quantity	Na^+	K^+	Cal.	Quantity	Na^+	K^+	Cal.
BREAKFAST												
Pancakes	2	282	77	112	3	423	115	169	4	564	154	225
Bacon	2	167	38	98	2	167	38	98	2	167	38	98
Pineapple Juice	1 C	2	375	138	1 C	2	375	138	1 C	2	375	138
Syrup	1 pack	1	10	104	1 pack	1	10	104	1 pack	1	10	104
Butter	1 pat	48	1	36	2 pats	97	2	72	2 pats	97	2	72
LUNCH												
Chicken Noodle	1 can	930	52	59	1 can	930	52	59	1 can	930	52	59
Hamburger - Raw	4 oz	39	458	235	4 oz	39	458	235	4 oz	39	458	235
Buns	1	215	45	115	1	215	45	115	1	215	45	115
Catsup	2 T	455	123	30	2 T	455	123	30	2 T	455	123	30
Lemonade	1 C	Trace	32	103	2 C	Trace	64	205	2 C	Trace	64	205
Jello	1/2 C	61	---	80	---	---	---	---	---	---	---	---
Custard	---	---	---	---	1 C	124	229	205	1 C	124	229	205
DINNER												
Tomato Soup	1 can	890	212	82	1 can	890	212	82	1 can	890	212	82
Turkey		123	616	268		123	616	268		123	616	268
Fine Rye Bread	1 slice	136	37	57	1 slice	136	37	57	1 slice	136	37	57
Cottage Cheese	1/4 C	163	50	54	1/2 C	326	100	107	1/2 C	326	100	107
Cranberry Juice	1 C	2	25	162	1 C	2	25	162	1 3/4 C	4	43	284
Butter	1 pat	45	1	36	1 pat	45	1	36	2 pats	90	2	72
Sherbert	1/2 C	5	22	129	1/2 C	5	22	129	1/2 C	5	22	129
Sugar Wafer Cookies	---	---	---	---	---	---	---	---	2	55	4	32
NIGHT SNACK												
Orange Juice	1 C	40	460	100	1 1/2 C	60	690	150	1 1/2 C	60	590	150
Sugar Wafer Cookies	---	---	---	---	2	55	4	32	2	55	4	32
		3604	2634	1988		4095	3218	2453		4338	3280	2699

DIET: Day III, No Exercise

Food	60 kg				70 kg				80 kg			
	Quantity	Na^+	K^+	Cal.	Quantity	Na^+	K^+	Cal.	Quantity	Na^+	K^+	Cal.
BREAKFAST												
Cream-O-Wheat	1 pack	273	17	107	1 pack	273	17	107	1 pack	273	17	107
Butter	2 pats	98	2	72	3 pats	147	3	110	3 pats	147	3	110
Brown Sugar	1 T	42	48	50	1 T	42	48	50	1 T	42	48	50
Toast	1 slice	116	24	63	1 slice	116	24	63	2 slices	233	48	126
Jelly	---	---	---	---	1 T	3	15	50	1 T	3	15	50
Grape Juice	1 C	6	300	160	1 C	6	300	160	1 C	6	390	160
LUNCH												
Beef Broth	1 C	940	135	30	1 C	940	135	30	1 C	940	135	30
Lamb Chops - Raw	1	25	233	151	2	49	466	302	2	49	466	302
Cottage Cheese	1/2 C	326	100	107	1/2 C	326	100	107	1/2 C	326	100	107
Toast	1 slice	116	24	63	1 slice	116	24	63	1 slice	116	24	63
Apple Juice	1 C	10	250	124	1 C	10	250	124	1 3/4 C	18	435	217
Sugar Wafer Cookies	2	55	4	32	2	55	4	32	4	110	8	64
Butter	1 pat	50	12	36	1 pat	50	12	36	1 pat	50	12	36
DINNER												
Beef Noodle Soup	1 can	870	73	64	1 can	870	73	64	1 can	870	73	64
Cubed Beef Steak - Raw	6 oz	75	462	328	6 oz	75	462	328	6 oz	75	462	328
Rice	1/2 C	1	36	101	1/2 C	1	36	101	1/2 C	1	36	101
White Bread or Roll	1 slice	116	24	63	1 roll	192	36	114	1 roll	192	36	114
Butter	1 pat	48	1	36	2 pats	97	2	72	2 pats	97	2	72
Catsup	1 T	227	62	15	1 T	227	62	15	1 T	227	62	15
Tomato Juice	1/2 C	240	273	25	1 C	480	545	50	1 C	480	545	50
Cup Cake - Chocolate frosting	1	198	69	211	1	198	69	211	1	198	69	211
Orange-Grapefruit Juice	---	---	---	---	1 C	9	416	96	1 C	9	416	96
NIGHT SNACK												
Ice Cream Bar	1	28	52	162	1	28	52	162	1	28	52	162
Oreo Cookie	---	---	---	---	---	---	---	---	1	55	4	57
		3860	2201	2000		4310	3151	2447		4345	3368	2692

Appendix IX: Subject Instructions and Extramural Protocol

While in the ambulatory pre- and post-bed rest phases, the subjects were instructed to record all activities in detail (see form number 5), and the times of their urination and defecation as prescribed in the general instructions detailed below. In addition, they were given written instructions (also detailed below) regarding their experimental commitments for each day.

General Instructions for Subjects

Activity

Record all activities immediately after they are concluded. Record and type activity within blocks of four hour periods and break down further your activity into the following catagories: sitting, standing , walking, or other activity. Describe the type of activity precisely, but briefly. Attempt to maintain sedentary habits and do not engage in vigorous exercise other than activity demanded during working hours.

Urination and Defecation

Always urinate before and after assuming a horizontal position for more than one hour. Try to urinate at least 5 times a day, about 3-4 hours apart. Measure the volume of each urine specimen, record the time, and empty from the volumetric flask into the 24 hour urine bottles. Fill up each bottle completely, mixing the urine after each addition. Carry a volumetric flask and urine bottle with you at all times. Bring the 24 hour urine to the Hospital each morning. Try to requlate your defecation within the same relative time period each day. If possible avoid defecating before your morning weigh-in. If any irregularity occurs, report it under the activity column. Record the time of each defecation under the activity column.

Sleep Habits

Sleep patterns will affect many of the physiological parameters being measured in this study. Take every reasonable precaution to avoid over-sleeping, and retire the same time each night. Avoid day time naps. Have your partner call you each morning at an agreed upon time.

Each Morning

When you report for weigh-in,deposit the previous day's extramural chart with Jim Fuller, along with the 24 hour urine collection. Pick up a new daily extramural chart, fresh urine bottles, and a daily master chart. The day of the experiment should be recorded under "expt'l day". Double check the date for accuracy.

Subject Numbers

Always include your number under your name, remembering that odd numbers denote exercising subjects, whereas even numbers are controls.

Daily Instructions

Day 0

Report to the Hospital by 9:30 p.m. You will sleep-in so that basal metabolism can be taken when you awaken.

Day 1

Arise between 6:00 a.m. and 6:15 a.m. Call your partner. Write under activity and record the time. Report to the Health Center by 6:45 a.m. When you arive, urinate just before you weigh, and record the time on your chart for that day. Discard the urine (at no other time throughout the experiment will you ever discard your urine), but collect all urine for the next 24 hours in the urine bottles. Weigh nude and record weight and the time. Pick up your daily master charts and urine bottles. Eat breakfast and record the time - write breakfast under the food column. Eat lunch between 12:00 and 1:00 p.m., record the time. Eat dinner between 6:00 and 6:30 p.m., record the time, and pick up your snack for the night. Retire between 10:00 and 11:00 p.m., write retired under activity and record the time. Urinate before retiring.

Day 2

Arise between 6:00 and 6:15 a.m. Call your partner. Record the time you arise on the day 1 chart. When you urinate before you weigh-in, record the volume of urine and the time (different time from the time you arise) on the day 1 chart. Add this urine to the 24 hour urine of day 1. Weigh nude. Turn in your 24 hour urine and your extramural chart. Pick up new urine bottles, new chart, and the master chart for that day.

Day 3-10

Arise between 6:00 and 6:15 a.m. and continue as on day 1.

Day 4

Report to the Hospital by 9:30 p.m. You will sleep-in so that basal metabolism can be taken when you awaken.

Day 8

Report to the Hospital by 9:30 p.m. You will sleep-in so that basal metabolism can be taken when you awaken.

Day 10

Report for dinner with all your things for the 9 day recumbency - or, after dinner, collect your things and report to the Hospital no later than 8:00 p.m. At the end of recumbency, continue with the same disciplined schedule as on days 1-10. You should record the food you eat and the time. Report for weigh-in at 6:45 a.m. You will continue to keep accurate water balance records, but will not save your urine; that is, just measure the volume and record the time. Do not eat or drink anything and do not defecate before you weigh-in.

NASA Project
Summer 1967

Form Number 5

Name________________ Subject Data - Extramural Date________________
Subject #____________ Weight a.m.__________
Expt'l Day___________ Time of Weight________
Expt'l Period________ Weight p.m.__________
Time of Weight________

TIME	VOLUME DRANK	VOLUME VOIDED	FOOD	ACTIVITY
00:00				
08:00				
12:00				
16:00				
20:00				
24:00				

Appendix X: Procedure for Underwater Weighing

Modified from technique of:

Goldman, R.F. and E. R. Buskirk. Body volume measurement by underwater weighing; description of a method, in J. Brozek (editor): Techniques for Measuring Body Composition. Washington, National Academy of Sciences - National Research Council, 1961, pp. 78-89.

1. Fill tank to proper level with water temperature of about 35°C.
2. Take nude body weight.
3. Determine subject's vital capacity.
4. Have subject enter the tank.
5. Have subject sit in underwater swing attached to scale.
6. Instruct subject as to the proper procedure for securing a valid underwater weight.
   a. Hold the front chains slightly below water level.
   b. Hyperventilate briefly and be sure to fully expire before bending over and submerging head underwater.
   c. Instruct subject to sit as relaxed as possible when fully suspended.
   d. Brushing against the side of the tank does not appreciably effect underwater weight unless the subject jerks away.
   e. Listen for a knock as the signal to return to the starting position.
7. Execute at least two practice trials before recording three official measurements.
8. Perform three weighings as described above.
9. Have subject remove himself from the swing and weigh it alone with water level constant.
10. Estimate residual volume from vital capacity, or measure directly.
11. Calculate body density from the following formula:

$$B = \frac{M_A}{\frac{M_A - M_W}{D_W} - V_R}$$

Where:

B_D = Body density

M_A = Mass in air (body weight in kg)

M_W = Gross weight underwater minus weight of harness underwater

D_W = Density of water

V_R = Estimated residual lung volume

12. Calculate percent of body weight that is fat from following formula:*

$$\% \text{ Fat} = \left[\frac{4.570}{B_D} - 4.142 \right] \times 100$$

*Reference: Brozek, J., et al. (1963).

PART III

RESULTS

The presentation of results follows the order detailed in the outline of experimental parameters given in Part I. The data was first analyzed on the basis of mean group response for a given experimental parameter with reference to time and/or experimental condition. A comparison between the exercise bed rest and non-exercise bed rest (internal controls) groups was then made in an attempt to determine whether differences in general response pattern existed. Finally, differences in the relationships of the various parameters included in the sub-headings of water balance, fluid compartments and electrolyte concentrations, renal function, and dietary components, were analyzed under the general heading of "Metabolism". In order to avoid duplication of numerical data in the presentation of results as described above, they were placed in Appendix I. To show the relationships in the trends of these parameters, graphs have also been included in Appendix I.

All data was processed by an IBM 7044 computer, and was analyzed by a program written by Dr. Richard Walters, School of Medicine, University of California, Davis. The program was designed to calculate group means, standard deviations, and graphs of mean values. The computer graphs are included in Appendix II. The basic data, including all individual values, are presented in Appendix III.

The non-bed rest subjects (external controls) were largely on their own recognizance during the day, i.e., between experimental obligations. A number of factors, particularly their failure to fully appreciate the importance of disciplined attention to detail, caused a number of irregularities and discrepancies that invalidated much of their data. Unfortunately, this was not discovered early enough to find replacements. Corrective and remedial measures during the experiment proved only partially effective. The basic data collected on these subjects is included in the computer print out. However, for reasons detailed above, it was decided not to attempt further analyses of their data, nor to compare it with that of the bed rest subjects.

Fluid Exchange

Assignments of subjects to one of the two experimental groups was based primarily on gross body weight measured at the beginning of the experiment. Additional factors resulted in a small difference in the average body size of the exercise group (1, 3, 5, and 7) and the control group (2, 4, 6, and 8). The mean body weights were 71.4 kg and 70.2 kg, respectively, while the lean body mass was 61.8 kg for the former and 60.1 kg for the latter group. Body surface area, as estimated by the formula of Dubois and Dubois, was 1.86 sq.m for the exercisers and 1.83 sq.m for the non-exercisers.

During the first three days of the equilibration period, the subjects were placed on a minimal water diet which resulted in a negative water balance of approximately 0.5 liters loss, except in subject number 2, who lost and regained 2.0 liters during this period. On the fourth day, water was added in proportion to the amount lost, and by the sixth day the exercise subjects were generally nearing a water balance of $\pm$ 0.2 liters. The control subjects regained water balance slower than the exercisers, and were not in balance until the 7th or 8th day of this period. Analysis of serum and urinary osmolality on days 1, 5, and 9 (day 10 for serum)[1] reveals a rise on day 5, with a return to day 1 values on days 9 and 10. Since their occupational environments varied, the average ambient temperatures experienced by each subject during the equilibration period can only be estimated; however, 80°F, with negligible air motion, was considered average. At this estimated average ambient temperature, the measured total water loss during the day was found to be greater than that accounted for by insensible water loss (IWL) alone. The average total sweat loss was 1.30 liters for the exercise group and 1.29 liters for the non-exercise group.

Since fluid intake and urine output values cannot be considered normal on days that renal function tests were run (a water load of 1.3 liters was ingested to stimulate a diuresis for subsequent collection of urine specimens), detailed analysis of fluid exchange on these days (10, 12, 15, 19, 21, and 27) was not done. The untreated data for all days, however, is included in the computer graphs. Referring to these graphs (Appendix II), enables one to see the distinct differences in values for the renal function test days as compared to an otherwise fairly regular fluid exchange pattern.

Fluid intake and urine output values presented in Table 3.1 are derived from days 6-9 of the pre-bed rest period. These values represent the amount of fluid consumed after a normal and stable water balance has been reached. Day 10, which was the last day of the pre-bed rest equilibration and was also a renal test day, is not included for reasons mentioned above.

At the onset of bed rest, fluid intake was adjusted according to the anticipated rate of evaporative water loss. Water allowances for the bed rest period were estimated from the night IWL during the preceeding period, which was assumed to be representative of 24 hour IWL in the resting state. Additional fluid adjustments were made for the exercise subjects in that their sweat loss was measured by weight loss following the standard 30 minute exercise bout. The average value of 0.19 kg on day 10 was doubled (since they were to exercise twice daily during the 9 days of recumbency) and added to their estimated 24 hour IWL. During bed rest the exercisers lost 680 gms/hour of sweat during exercise. This method of fluid adjustment proved to be adequate, in that it was observed that the exercisers increased evaporative loss by nearly the amount of supplementary fluid added to their diet, while the non-exercising controls also demonstrated a decrease in 24 hour evaporative water loss by approximately the amount that their dietary water intake was reduced. Hence, in both groups, the only alteration in water exchange that would result in a negative balance was an increased urine flow. Fluid allowance estimated by the above method was in excess of requirements by 60 ml for the exercisers and 30 ml for the controls.

---

[1]Serum was collected at 0800; hence day 1 serum was taken just one hour after the first experimental day began.

		Exercisers	Controls (Non-exercisers)
Fluid intake:	PBR	2.50 liters	2.40 liters
	BR	2.65 liters	2.14 liters
	BRrt	3.06 liters	2.64 liters
	R	2.88 liters	2.92 liters
Urine output:	PBR	1.28 liters	1.13 liters
	BR	1.35 liters	1.26 liters
	BRrt	1.63 liters	1.60 liters
	R	1.25 liters	1.23 liters
Evaporative loss:	PBR	1.30 liters	1.29 liters
	BR	1.39 liters	1.00 liter
	R	1.53 liters	1.68 liters
Night Insensible Water Loss (IWL)	PBR	45 gms/hr	35 gms/hr
	BR	44 gms/hr	40 gms/hr
	R	45 gms/hr	43 gms/hr
Day Insensible Water Loss (IWL)	BR	27 gms/hr	41 gms/hr
Average Water Balance	PBR	- 80 ml	- 20 ml
	BR	- 90 ml	-120 ml
	BRrt	+ 40 ml	+ 40 ml
	R day 20	+750 ml	- 40 ml
	R day 21	+100 ml	+100 ml
	R day 22	+118 ml	+610 ml

TABLE 3.1. AVERAGE FLUID EXCHANGE FOR THE THREE EXPERIMENTAL PERIODS. The addition of a 1.3 L water load and approximately 260 ml of isotonic saline infusion on renal function test days made those days inappropriate for the study of normal physiology. Since they do represent changes that nevertheless occur, they must be considered in the overall water balance analysis. Including these days in water balance shows an opposite trend on days of renal tests, with an apparent retention of water. The serial change of water balance on the first three ambulatory recovery days is shown to demonstrate the rate of recovery (PBR=pre-bed rest equilibration of 10 days; BR=bed rest period with the 3 days of renal tests excluded from averages; BRrt=bed rest period including all 9 days; R=recovery or post-bed rest period of 7 days, except where noted).

Insensible water loss, which was calculated for both the "day" (0700-2300) and the "night" (2300-0700) periods during bed rest, was variable among individuals, yet group averages were reproducible within each of the three periods. Twenty-four hour evaporative loss averaged 50 ml higher on renal function test days, and might be attributed to some anxiety manifested by the subjects. Night IWL varied ± 10 gms/hr and appeared to be independent of water balance. During the ambulatory periods, the night IWL reflected the amount of activity during the corresponding day.

Urine flow rates were calculated for "day" (0700-2300) and "night" (2300-0700) periods. There was a marked difference of urine flow rates during the day in pre-bed rest versus bed rest periods, but night flow rates were maintained at approximately 0.67 and 0.63 ml/min in exercisers and controls, respectively. The average "day" flow rate during bed rest varied markedly on the days of renal function tests, but was little changed in "night" flow rates. Thus, the diuresis response observed during bed rest is apparently manifested in the "day" urine flow rates, since the "night" urine flow rates were rather stable throughout the entire experiment, and did not manifest a similar response pattern. These observations are summarized in Table 3.2.

The two groups demonstrated a similar pattern of response to water loads during the renal function tests, as is depicted in Figure 3.1. Because of unexpected procedural delays, e.g., a subject's inability to urinate at the scheduled time, the total delivered volume of infusate (containing PAH and inulin) varied ± 50 ml with each experiment. Two and one half hours after the water load was consumed, all subjects had not completely excreted the water ingested. On the last day of the equilibration period (day 10), and on days 12 and 15, the exercise group retained approximately 60% of the fluid, while the controls retained approximately 50% of the 1.5 liter load. On the last day of bed rest, both groups increased their volume of excretion, as the exercise group retained 50% while the controls retained only 20%. On days 21 and 27, both groups retained approximately 10%, indicating a markedly increased excretion of urine in comparison to the pre-bed rest volumes recorded on day 10.

In some instances the increased production of urine during renal function tests appeared to be slightly related to serum osmolality (see Figure 3.2). A blood sample was taken 36 min (± 7 min) after the ingestion of the first part of the water load (800 ml). The values for serum osmolality measured on days 10 through 27 had a downward trend, while urine production during the 2½ hour renal tests steadily increased. The change in mean serum osmolality from days 10 to 27 was 285 to 274 mOsm/L in the exercisers and 283 to 274 mOsm/L in the controls. However, on some days the osmolality was slightly higher than on day 10; hence, the trend was not consistent. A second blood sample was taken 45 min after the ingestion of 500 ml additional water load (or 1 3/4 hour after the first blood sample). In the exercise subjects the values for this sample were consistently higher

Period	Group	PBR	BR	BRrt	R
Day rate	Exercise	1.02	1.42	1.12	0.91
	Control	0.89	1.32	1.03	0.80
Night rate	Exercise	0.72	0.65	0.64	0.79
	Control	0.60	0.65	0.62	0.66

TABLE 3.2. DIURNAL VARIATION IN AVERAGE URINE EXCRETION RATES. The three periods (PBR, BR, and R) have average urine flow rates divided into a 16 hour "day" period (0700-2300) and an 8 hour "night" period (2300-0700), during which time the subjects were consistently recumbent in all periods. See Table 3.1 for abbreviations.

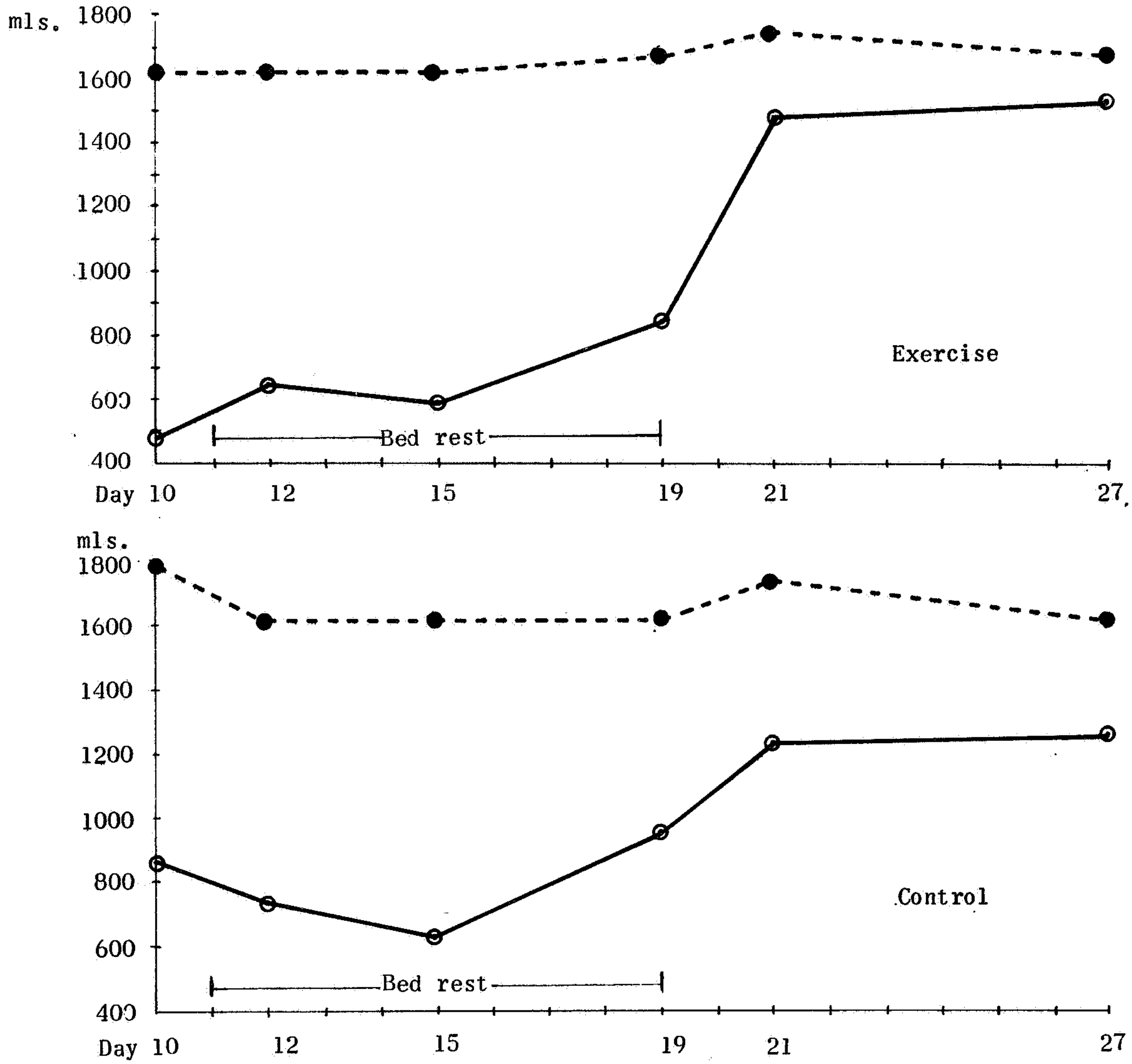


FIG. 3.1. AVERAGE VOLUME OF URINE EXCRETION DURING TWO AND ONE HALF HOURS FOLLOWING THE INGESTION OF A LOAD OF DISTILLED WATER. Plotted water load values include infusate volume. Exercisers are shown in the upper graph, controls in the lower graph. The load of water occasionally varied by 250 ml in one or two subjects due to delays in protocol and necessitated the additional water to assure a constant and elevated urine flow during the renal function tests (day 10 in controls and days 19 and 21 in both groups); on all other days, constant volumes of water were consumed (●- -● urine output; ○——○ water input).

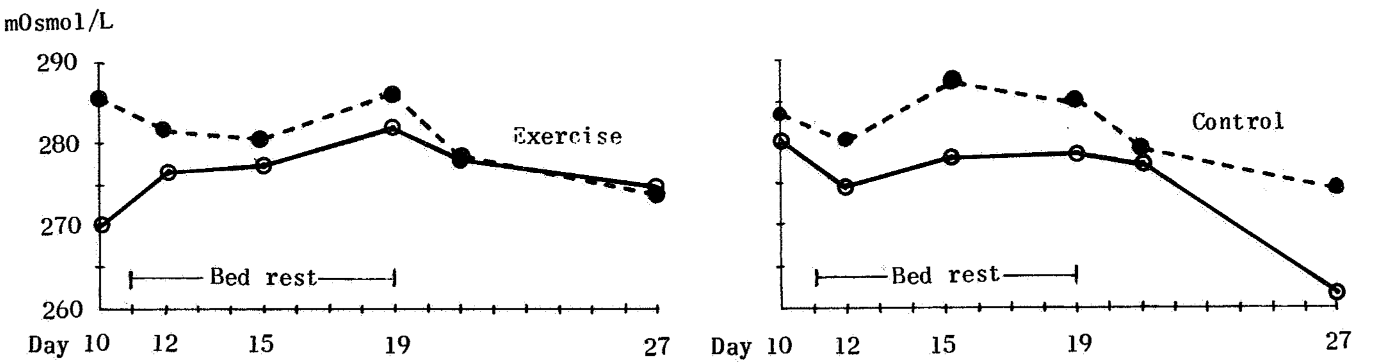


FIG. 3.2. SERUM OSMOLALITY AT THE BEGINNING AND END OF RENAL FUNCTION TESTS. Blood samples were taken after each prescribed water load had been ingested during renal function tests, which included 30 minutes of exercise following the second water load. Control subjects did not exercise during bed rest (36 minutes after 800 ml●- - - -● ;1 3/4 hour after 800 ml and 3/4 hour after 500 ml○——○).

during bed rest than on day 10 when serum osmolality was 270. On the other hand, the control subjects demonstrated a decrease on days 12 and 15 relative to the day 10 value of 280 mOsm/L. However, on days 19 and 21, when urine production markedly increased, the serum values for the control group increased to the level recorded on day 10. The controls urine production on day 27 was similar to that on day 21, yet serum osmolality decreased from 278 to 261 mOsm/L on the latter day. Hence, it appears that only the serum osmolality values for the first sample demonstrated any relationship to the trend of urine production during renal function tests.

Since body weight was routinely measured at 0700 every morning, it served as a reference for the calculation of 24 hour evaporative water loss and serial weight change. All subjects lost an appreciable amount of weight on day 1, ranging from 0.5 to 0.8 kg, except subject 2, who as mentioned above, lost 2 kg. These weight losses were due largely to an unintentional restrictive water allowance that was subsequently increased. In the later stages of the equilibration period (day 10) the subjects had very nearly regained their beginning weights (average discrepancy of -0.4 kg).

During bed rest the exercisers' 24 hour weights fluctuated ± 0.4 kg, a variation easily attributable to changes in water balance. They manifested no clear measurable trend in weight gain or loss. Conversely, the controls demonstrated relatively more constant body weights (within a range of ± 0.2 kg), and a progressive weight loss of 0.7 kg midway through bed rest (day 15). However, they regained 0.2 kg during the remaining days of recumbency.

Fecal Loss

A low residue dietary regimen was employed to minimize the procedureal problems of handling and moving subjects for bowel movements during bed rest. The dietary regimen proved entirely satisfactory in this respect, reducing the average number of bowel movements from 6 per 10 days before bed rest to 2.5 in nine days of bed rest. Average fecal weight loss during bed rest was 80 gms per day, with the average weight of each stool being 240 gms. One subject (number 7) did not defecate during the entire bed rest period and on day 20 produced a stool estimated to weigh 450 gms.

Body Fluid Volumes

On day 10 of the equilibration period, total body water (TBW) averaged 52.09 L for exercise subjects and 52.26 L for controls. At the end of bed rest (on day 19), the averages were 52.01 L and 49.52 L for the exercise and control subjects, respectively. The method of injecting one millicurie of tritium intravenously and collecting three serial blood samples was found to have a large average variation. In 20 individual measurements, the variation between the three different samples was ± 2 L in six, and ± 4 L in one measurement. However, the variation in these seven measurements was usually present in only one of the three samples, with the other two samples varying only ± 0.5 liters. The remaining 13 measurements had ± 0.4 L variation in the three samples collected.

The only appreciable error involved in the isotope method of determining blood and plasma volume was in preventing any perivascular leakage when the RISA was injected intravenously. Blood volume tended to follow a pattern identical to that of plasma volume in both groups throughout the experiment. Compared to day 10 values, both the exercisers and controls showed a loss of blood and plasma volume on day 12, with a further loss on day 15 (see Appendix I). This trend was reversed on day 19, and was followed by a further increase on day 21, with the latter level being maintained on day 27. The two groups did evidence differences in magnitude of changes, in that the serial measurements of blood and plasma volumes in the beginning of bed rest revealed a consistently greater decrease for the controls. On day 10, the exercisers had a mean plasma volume of 3.24 L and the controls 3.20 liters. On the fifth day of bed rest, exercise and control subjects had plasma volumes of 3.04 L and 2.84 L, or 6% and 11% lower than pre-bed rest measurements, respectively. On day 19, the plasma volume of the exercise group returned essentially to that of day 10, while that of the controls was 7% lower. After one day of ambulation (day 21), the exercise group showed an increase of 5.6% in their original volume of 3.24 L, while the control group volume was 2.9% less than on day 10. Plasma volumes on day 27

Group	Day 10	12	15	19	21	27
Exercise	2.390	2.400	2.240	2.400	2.340	2.290
Control	2.420	2.480	2.420	2.470	2.410	2.370

TABLE 3.3. RED CELL VOLUME BEFORE, DURING, AND AFTER BED REST. Red cell volumes were calculated by subtracting plasma volume from blood volume.

were slightly lower than those of day 21 in both groups. Red blood cell (RBC) volume did not vary greatly and evidenced no consistent pattern. (See Table 3.3).

Blood Electrolytes

During equilibration, sodium potassium, chloride, and osmolality concentrations followed the same trend for both groups. On day 5 increased concentrations relative to day 1 were observed, followed by a return to initial levels on day 10. Since there was some disturbance in these measures in the early stages of equilibration due to the unstable initial water balance, the day 10 concentrations are regarded as compensated equilibration values and serve as baseline reference values for subsequent bed rest and post-bed rest observations.

Mean serum sodium concentration on day 10 was 137 mEq/L and 135 mEq/L for the exercise and the control subjects, respectively. Both groups showed an increase of 2-3 mEq/L on days 12 and 15. Following nine days of bed rest (day 19), the exercise subjects had dropped 2 mEq/L below day 10, while the control group demonstrated an elevated level of 1 mEq/L. On the final day (day 27), both groups showed a further drop of slightly different magnitude, each recording a mean concentration of 132 mEq/L. Thus, there was a gradual downward trend in both groups following the second day of bed rest, with the control subjects maintaining a slightly higher sodium concentration until the final day of recovery.

The pattern for the serum potassium concentration was dissimilar, in that only the controls showed an upward trend. The average for the exercise subjects during the entire experiment was 3.7 $\pm$ 0.2 mEq/L, while that for the control subjects rose from 3.6 mEq/L on day 10, to 4.0 mEq/L on day 27, although during bed rest, values for the latter group were relatively stable, with a measured increase of 0.1 mEq/L. The exercise group had a mean serum potassium concentration on day 12 that was slightly increased over the baseline value on day 10, but which dropped subsequently and remained depressed for the duration of bed rest. However, immediately following bed rest (day 21), the potassium levels rebounded to 3.8 mEq/L and changed little during recovery.

The trend for chloride concentration after day 10 in the exercise group was similar to that observed for potassium, in that minor fluctuations between 98-99 mEq/L were observed. However, the day 10 baseline value was considerably higher (102 mEq/L). The control subjects also had a discernible bed rest effect with an average 2 mEq/L decrease relative to the concentration of 100 mEq/L measured on day 10. During recovery, except for a transitory increase to 100 mEq/L on day 23, the serum concentration of both groups was little changed from bed rest.

Serum osmolality has been mentioned previously in connection with its relation to water loads and urine volume. The general response pattern in the two groups for the first sample taken before the renal function test showed that the control subjects were consistently 1-2 mOsm/L lower than the exercise group. At the midpoint of bed rest (day 15) the control subjects had an average serum level 5 mOsm/L higher than the exercise group. The two groups followed an identical pattern on all other days. Relative to experimental day 10, the exercise subjects had depressed osmolalities of 4 mOsm/L on days 12 and 15. On day 19, values had returned to the baseline value of 286 mOsm/L. Following bed rest, the exercise group's osmolality dropped considerably to 274 mOsm/L. The control subjects had a value of 280 mOsm/L on day 12, which was 3 mOsm/L less than their baseline value. On days 15 and 19, the values were 285 mOsm/L compared with 283 mOsm/L measured on day 10. The control group also showed a steady decrease (to 275 mOsm/L) on day 27.

Serum creatinine levels remained essentially unchanged in both the exercise and control groups. The mean serum concentration was 1.10 for both groups on day 10, and varied by only ± 0.1 mg/100 ml throughout the remainder of the experiment.

Renal Function

The resting levels of renal plasma flow (RPF) in stable physiological states were reasonably repeatable in separate measurements. This observation was first substantiated by the fact that, in seven of the eight bed rest subjects, resting clearances (measured in pilot studies before the experiment) varied only ±50 ml/min with determinations made on day 10 of the equilibration period. Although, on occasion, as many as 6 clearances were determined within a given experimental day, RPF was usually determined by a minimum of two 15 minute clearance periods at rest, which varied ± 30 ml/min, or 10%.

Since clearance determinations in this study depended upon each subject emptying his bladder in the recumbent position, a source of unmeasureable error was introduced. However, incomplete voiding could be detected in the case of two consecutive clearances that were grossly different (more than 20%). Therefore, the serial sampling technique, plus the pooling and redetermination of an average RPF for an obviously high value with a preceding low value, was employed as a back-up analytical technique. For example, if two clearances were taken and the first was low (due to an incomplete bladder emptying), while the second was high, it was assumed that the second sample contained the urine not voided after the first clearance. Hence, the urine collected for the two periods was pooled and assumed to represent all urine produced during the combined periods, while the corresponding two serum samples collected were averaged. The validity of this procedure was substantiated when subsequent clearance periods during the same test were conducted and found to agree with the corrected pooled values.

On day 21 (the first 24 hours of post-bed rest), all clearances determined at rest in subjects 5 and 7 appeared exceptionally high and erratic at levels of 1200 ml/min ± 300 ml. In addition, subject 1 had two very different resting RPF values. These clearances could not be justified by unequal bladder emptying and are deleted from the report. Thus on day 21, only the clearance measured for subject 3 was deemed valid.

The exercise subjects had little change in RPF during bed rest, their average clearances varying only ± 15 ml/min. There was a slight drop registered on days 12 and 15, followed by an increase to approximately 730 ml/min on day 10. The exercise group's RPF value on day 27 was essentially the same as pre-bed rest, averaging only 40 ml/min higher than the clearances measured on day 10. The control subjects, on the other hand, displayed a distinctly different pattern during bed rest, demonstrating a consistent rise from a day 10 value of 590 ml/min to 790 ml/min on day 19. On day 21 (post-bed rest) these subjects registered a continued increase with an average clearance of 250 ml/min above the pre-bed rest clearances of day 10. Six days later (day 27) their RPF dropped somewhat, but was still 100 ml/min above the day 10 baseline value.

Glomerular filtration rate (GFR) was determined by exogenous (inulin) and endogenous (creatinine) methods. The method of analysis of inulin presented technical difficulties and consequently inulin concentration in serum and urine was not considered to be reliable. GFR (as determined by creatinine clearance) was measured in periods lasting for 24 hours at prescribed intervals during the experiment. In three separate measurements before bed rest the exercise subjects were found to have an average GFR of 134 ± 4 ml/min. The control subjects had an average clearance of 133 ± 2 ml/min during this period. On day 11 the exercisers had a GFR of 155 ml/min, however, during the remainder of bed rest their GFR decreased to a value 10 ml/min above the pre-bed rest baseline value observed on day 9.

Following bed rest (day 23), their GFR dropped to 10 ml/min lower than the baseline value. The trend observed in the control subjects was less variable. After dropping from an average pre-bed rest value of 133 ml/min to 125 ml/min on day 11, there was a gradual rise to 145 ml/min on day 18. After bed rest, the controls demonstrated a steady decrease below the baseline level.

Creatinine clearance at night (2300-0700) was determined on four subjects (5, 6, 7, and 8) during the three periods (see Table 3.4). Average difference between the two clearance periods was the same for all three experimental periods, showing no apparent pattern in either pair of subjects. The average fall of GFR at night was determined as percent of the 24 hour clearance value. The average nighttime clearance was 83% and 76% of the 24 hour GFR for the two exercisers and the two controls, respectively.

Urinary Electrolytes

All urinary constituents measured were determined from 24 hour pooled urine collected the day before or after renal function tests. The urinary concentrations were multiplied by urinary volume per unit time and expressed as amount per unit time (mEq/L x L/day). Graphs of each electrolyte appear in Appendix I of Part III. Urine concentrations (mEq/L) are presented in less detail than the quantity of any constituent excreted per day (mEq excreted per day), since the effects of water volume on concentrations is excluded in the latter parameter. Analysis of free water exchange is presented later in the section dealing with urinary osmolality.

The 24 hour sodium concentration in exercise subjects dropped slightly throughout bed rest, markedly decreased further on day 20, and rose only slightly by day 27. Sodium output measured in mEq/day was very similar in pattern, but showed a greater absolute decrease during bed rest. On day 11, sodium output was increased over the day 9 level of 279 mEq/day by 30 mEq/day. Thereafter, sodium output for the exercise subjects gradually decreased to 232 mEq/day, or 50 mEq lower than the day 9 pre-bed rest baseline value. Upon returning to normal ambulatory activity on day 20, sodium excretion dropped abruptly to 130 mEq/day, or approximately 50% of that observed before bed rest. The excretion rate did not return to day 9 levels during the following week.

The sodium concentration and output trend was nearly identical in both groups, varying only in the magnitude of changes. On day 11, the controls excreted 302 mEq/day, or approximately 40 mEq/day more than their pre-bed rest baseline value. After day 11, sodium output decreased slightly, until day 20, when bed rest was terminated. The output of 93 mEq/day on day 20 was less than 50% of the last value measured during bed rest, and less than 30% of the output of day 11.

Subject	Day 9	11	14	18	20
5	--	--	111	104	136
7	89	101	108	99	75
$\bar{x}$% of 24 hr pool	87	71	86	82	87
6	--	--	73	111	136
8	138	121	--	147	122
$\bar{x}$% of 24 hr pool	81	85	51	84	81

TABLE 3.4. NIGHT (2300-0700) CREATININE CLEARANCE AS COMPARED TO 24 HOUR CLEARANCES. On selected days during the 27 day experiment, a sample of the night urine collection was measured and compared with the 24 hour pooled urine (which included the night urine). Average night clearances for each pair are expressed as percent of the 24 hour value. Subjects 5 and 7 were exercisers and 6 and 8 were bed rest controls.

The comparison of the changes in sodium output between controls and exercise subjects can be misleading unless dietary factors are considered. The dietary regimen prior to bed rest had the same sodium content for both groups; however, during bed rest, dietary sodium of controls was 40 mEq/day less than that of exercisers, and in both groups dietary intake was reduced from equilibration levels during bed rest (see Appendix VIII, Part II). Further data on electrolyte balance is presented later in the section on electrolyte metabolism.

Variations in potassium concentration and excretion were similar in both groups throughout the experiment. Potassium output decreased on day 11, to approximately 20 mEq/day less than the amount excreted in the pre-bed rest period. Three days later (day 14) the exercise and control subjects were excreting approximately 70 and 60 mEq/day of potassium, respectively. These levels of excretion continued on days 16, 18, and 20, varying in either group by only $\pm$ 6 mEq/day. The exercise group demonstrated a reduced excretion level of 45 mEq/day on days 23 and 26, whereas the controls excreted approximately 55 mEq/day, essentially unchanged from bed rest observations.

Controls had a higher urinary chloride concentration on day 11 than on day 9, whereas the exercise group had a similar value on both days. Chloride concentrations in both groups registered a downward trend beginning with day 11, with both groups demonstrating a reduced chloride excretion (relative to pre-bed rest values) on day 20. On the other hand, chloride output trends were dissimilar in the two groups. The exercisers' output on day 9 was 282 and the controls' was 234 mEq/day. The chloride output in the exercise group remained the same on day 11, while the controls showed an increased output of 30 mEq/day. After day 11, the exercisers' output was relatively unchanged, followed by a second decrement in excretion of chloride on days 20 and 23 to 186 and 161 mEq/day, respectively. By the end of post-bed rest (day 26), the exercise group's chloride output began to rise slightly. In contrast the controls had a slight increment on day 11, followed by a clear downward trend during the remainder of bed rest, ending in a very large drop on day 20 when the output was 100 mEq/day, or 170 mEq/day less than the pre-bed rest baseline value. The control group continued to excrete very low levels throughout the recovery period.

Urinary osmolality in the exercise subjects tended to fluctuate greatly and, with the exception of day 26, the average values were only slightly decreased during bed rest and recovery. The controls were very much below pre-bed rest baseline values throughout bed rest and recovery. However, by converting mOsm/L to mOsm/day (mOsm/L x urine vol/day) i.e., osmotic output, a different pattern is revealed. Controls and exercisers had the same output on day 9, whereas the former averaged lower excretion rates during bed rest than the exercisers. Both groups had a consistent slow decline throughout post-bed rest, resembling the urinary excretion curve of sodium.

Urinary osmotic concentration and outputs were plotted for the two groups in such a way that changes of one parameter relative to the other can be compared with day 9, when both osmotic concentration and output start from the same point. By this method, an estimate of free water clearance can be made, since a rise in concentration over that of osmotic output represents a decreased proportion of water to solute, and, likewise, a dilution of solute by water will show a concentration lower than osmotic output.

The exercise group during bed rest had a higher level of concentration than osmotic output relative to the day 9 levels, indicating an increased osmotic excretion proportional to free water. The controls had a larger osmotic output relative to concentration levels on days 11 and 14, indicating an increased solute excretion, whereas this pattern was reversed on days 16 and 18. Both groups showed a greater retention of solutes (i.e., a decreased excretion) than water following bed rest.

A pattern similar to the above can be seen with the conventional calculation of osmotic (C_{Osm}) and free water (C_{H_2O}) clearances by the formulas below:

$$C_{Osm} = V \times U_{Osm}/P_{Osm}; \quad C_{H_2O} = V - C_{Osm}$$

(where U refers to urinary, P to plasma, and V to urine volume per unit time). The daily averages are plotted in Figure 3.3, while the corresponding calculated values appear in Table 3.5. The exercise subjects show a generally decreasing osmotic excretion relative

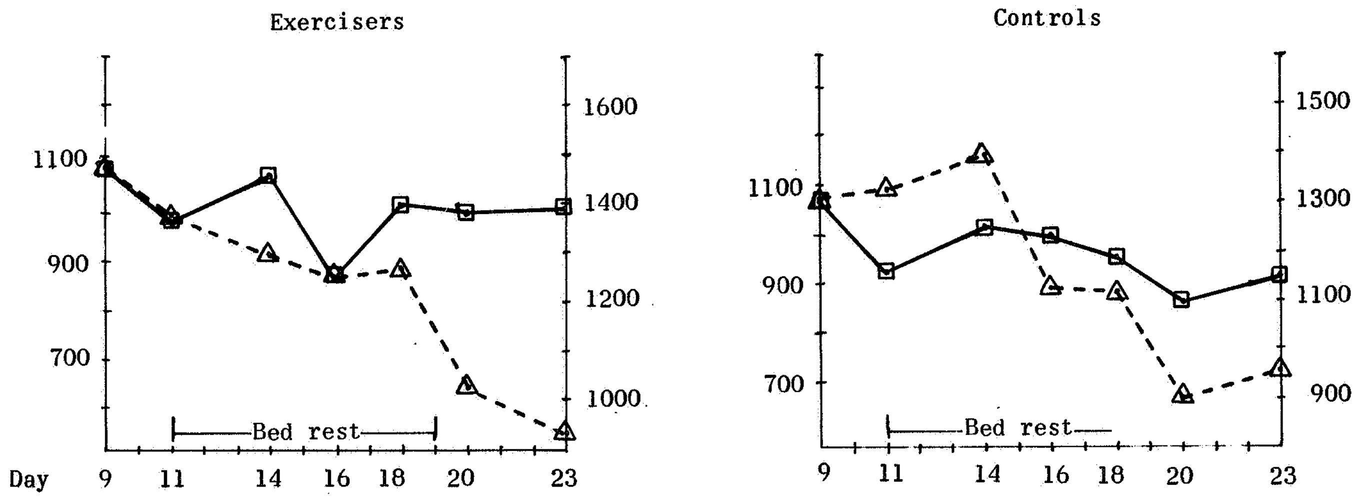


FIG. 3.3. URINARY CONCENTRATION AND EXCRETION OF SOLUTES. Osmolality concentration and output are plotted on the same abcissa with the right ordinates adjusted so that the two parameters begin at the same point on day 9. The two pairs of ordinates for exercise and control subjects have the same incremental scaling (units/inch) for comparison of the magnitudes of difference between the two parameters in the two groups of subjects (left ordinates represent scaled values for mOsm/L and symbols for the corresponding values are ⊟——⊟ ; right ordinates represent scaled values for mOsm/day, symbols for corresponding values are △ - - △).

to free water. The controls show a higher osmotic clearance on days 11 and 14, which diminished on days 16 and 18. In both groups, free water clearance was increased on days 20 and 23, whereas osmotic clearance was decreased.

Aldosterone analysis was completed for 3 of the 4 subjects in each group, on days 10 and 19 (see Table 3.6). The results are somewhat variable, in that two of the exercisers had an increased aldosterone excretion, while two controls manifested a decreased excretion. Subject 3 decreased excretion, while subject 6 increased, and, thus, each had opposite patterns to the other two in their group.

	Day	1	5	9	11	14	16	18	20	23
Exercisers	C_{Osm}	3.12	3.50	3.49	3.54	3.34	3.45	3.24	2.50	2.41
	C_{H_2O}	-2.32	-2.61	-2.57	-2.53	-2.47	-2.33	-2.33	-1.80	-1.74
Controls	C_{Osm}	2.39	2.92	2.98	3.17	3.15	2.96	2.94	2.40	2.49
	C_{H_2O}	-1.79	-2.21	-2.20	-2.21	-2.26	-2.11	-2.06	-1.60	-1.72

TABLE 3.5. OSMOTIC (C_{Osm}) AND FREE WATER (C_{H_2O}) CLEARANCES FOR EXERCISE AND CONTROL SUBJECTS. Three days during equilibration, four days during bed rest and two days during recovery are listed. Blood samples were measured on the morning (0700) concluding a 24 hour pooled collection of urine, except on days 1, 5, and 23, on which the blood samples were taken on the morning beginning the 24 hour period.

Subject	Day 10	19	Subject	Day 10	19
3	23	16	2	34	19
5	16	22	4	22	10
7	13	18	6	8	19
Mean	18	19		21	16

TABLE 3.6. ALDOSTERONE EXCRETION BEFORE AND AT THE END OF BED REST. Aldosterone (μgm/24 hours) was measured at the beginning and at the end of bed rest on 3 out of 4 subjects in the exercise (3, 5, and 7) and control (2, 4, and 6) groups.

Urinary creatinine output for the exercise group during bed rest showed no pattern varying from the average value observed in pre-bed rest (2.25 ± 0.05 gms/day). The average excretion during bed rest was 2.29 gms/day. After bed rest, however, values dropped to 2.0 gms/day on day 20 and 1.85 gms/day on day 23. The controls excreted approximately the same amount of creatinine throughout bed rest as they had in pre-bed rest measurements (2.18 ± 0.10 gms/day). However, their creatinine output dropped to 1.9 gms/day on day 20 and to 1.85 gms/day on day 23.

Additional Urinary Measurements

Titratable acidity and sulfate were not part of the original design, but were measured on selected days as shown in Tables 3.7 and 3.8. Titratable acidity was measured by titrating urine to a pH of 7.4 with 0.1N NaOH. Inorganic sulfate was measured by the method of Folin (Hawk et al., p. 947, 1954).

Titratable acidity was 39 mEq/L in both groups on day 9. During bed rest, the exercisers showed a decrement to approximately 30 mEq/L and continued to excrete that amount throughout bed rest and recovery. In contrast, the control subjects evidenced a large drop to 16 mEq/L, and continued to excrete that amount during bed rest and recovery. On day 15, a low average was recorded and was attributed primarily to one subject (6) who registered a negative value. The other three individuals were relatively unchanged on that day.

Subject \ Day	9	13	15	21	23	26
1	38.0*(5.8*)	31.3 (6.3)	20.8 (6.3)	31.8 (6.5)	40.9 (5.8)	24.4 (6.3)
3	45.3 (5.3)	38.5 (5.7)	35.8 (5.7)	39.5 (5.7)	34.2 (5.6)	25.7 (5.6)
5	38.8 (5.6)	18.5 (6.3)	41.8 (6.0)	22.7 (6.4)	13.2 (6.2)	26.3 (6.2)
7	36.0 (5.7)	17.4 (6.6)	39.4 (6.5)	10.5 (6.9)	14.3 (6.4)	35.8 (5.5)
x	39.0 (5.6)	26.4 (6.2)	34.4 (6.0)	26.1 (6.3)	25.6 (6.0)	28.0 (5.9)
2	56.1 (6.2)	32.3 (6.0)	29.5 (5.8)	30.0 (6.0)	18.7 (6.2)	23.4 (5.7)
4	23.4 (6.3)	4.1 (7.0)	11.2 (6.9)	14.5 (6.7)	13.0 (6.0)	17.9 (6.0)
6	23.1 (6.0)	11.2 (6.7)	-37.3 (8.6)	19.7 (6.1)	20.5 (6.2)	25.9 (6.0)
8	52.3 (5.9)	14.5 (6.6)	12.4 (6.7)	16.3 (6.5)	8.4 (6.5)	7.8 (6.9)
x	38.7 (6.1)	15.5 (6.6)	3.9 (7.0)	20.1 (6.3)	15.1 (6.3)	18.7 (6.1)

TABLE 3.7. URINARY TITRATABLE ACIDITY (mEq/DAY). Urine specimens were taken from 24 hour pooled urine on selected days and expressed as mEq/day of hydrion. Urinary pH appears to the right of each value in parenthesis (*estimated, urine was not available).

Subject	Day 9	13	15
1	93.7*	97.4	95.0
3	74.4	61.8	54.4
5	74.4	55.0	76.8
7	49.1	56.3	65.0
x	72.5	76.4	72.5
2	120.5	89.4	48.2
4	86.7	54.4	55.0
6	41.3	43.4	43.4
8	88.0	71.2	83.1
x	83.7	64.4	57.5

TABLE 3.8. URINARY SULFUR (mEq/DAY). See Table 3.7 for explanation.

Sulfate levels on day 9 averaged 70 mEq/day, and remained virtually unchanged on the other two days analyzed for the exercise group. The control group had a sulfate excretion of 84 mEq/day on day 9 (pre-bed rest), but showed a decrement of approximately 20 mEq/day on day 13, with an additional drop of 7 mEq/day on day 15.

Electrolyte Metabolism

A study of the exchange and balance of electrolytes (sodium, potassium, and chloride), especially as it pertains to their interrelated, compensated or disordered states, permits a more fundamental view of these physiological events during bed rest. This type of analysis necessarily requires a number of calculated and derived values of dietary, urinary, and serum constituents and, hence, each of these three parameters were changed to values representing the amount lost or gained in mEq/day.

The extracellular fluid (ECF) electrolyte content was calculated by assuming standard values of 13.5 and 13.2 L as representing ECF volume in the exercisers and controls, respectively. These values were derived from measured blood volumes and known ECF volumes after the method of Edelman and Leibman (1959). The ECF volume multiplied by the serum concentration yields an approximate ECF electrolyte content in mEq, the values of which are included in Table 3.9. In this form, serum electrolyte concentrations can be employed in the assessment of electrolyte metabolism. However, the validity of these calculated values are limited to the analysis of the constituents within one day, since day to day evaluation must be considered concomitantly with changes in ECF volume due to efflux or influx of free water.

Urinary electrolytes have been analyzed with respect to input-output balance, and with respect to baseline equilibration levels (day 9, which was assumed to be the normal level of excretion in the ambulatory state). Since the dietary electrolyte input was reduced in both groups during the bed rest period, there are problems in attempting to make comparisons. In addition, potassium input-output could not be calculated precisely due to the extra-renal excretion of this electrolyte in the stools, which was not measured. This problem does not exist in the case of sodium and chloride input-output, since the only route by which these two constituents are excreted extra-renally is in the sweat (excluding small amounts in the stools). The urinary output values are given in Table 3.9 under their respective columns labeled "urine mEq/day." It may be seen that on day 9, the number that appears above the output value in parenthesis for all three electrolytes represents a corrected baseline level. This value was obtained by the following formula:

Day 9 urinary output - (pre-bed rest dietary intake - bed rest dietary intake)

Potassium balance was obtained by subtracting the corrected urinary value from all bed rest urinary values, and appears as a "corrected balance" (see column under potassium entitled "Corr bal").

Cumulative input-output balances for sodium and chloride, and cumulative corrected balances for potassium were obtained for each day during bed rest (days 11, 14, 16, and 18). A cumulative corrected balance for sodium and chloride (corresponding to the method of balancing potassium) appears above the day 18 value (see column entitled "cum bal"). The cumulative balance was calculated by adding the balances for each day; hence, the day 18 value represents the total amount lost or gained during the four days of bed rest selected for analysis.

On days 12 and 15, extracellular sodium levels were approximately 40 mEq above the day 10 values of 1840 mEq for the exercisers and 1777 mEq for the controls (see Table 3.9). After day 15, both groups showed a consistent decrease until day 27 (the trends for electrolyte values in the serum and ECF are identical in pattern, of course, since the former is merely multiplied by a constant to obtain the latter value). The changes in this parameter relative to the day 10 baseline values are given under the column "ECF bal". Most individual sodium balance values, as calculated by input-output, were negative on day 11, showing a mean deficit of -72 mEq for the exercise group and -104 mEq for the control group. Except for day 14, on which the exercisers showed a slight positive balance, both groups revealed a continued negative sodium balance, amounting to a cumulative balance of -94 mEq for the exercise group and -140 mEq for the controls on day 18. (Balances determined by a corrected day 9 value were -114 and -244 mEq, respectively, for the two groups.)

Average total ECF potassium measured during bed rest increased by 5 mEq on day 12 in the exercise group, but thereafter showed a small decrement from the baseline value of approximately 2.5 mEq. "Corrected" urinary potassium balance indicated a slight but progressive potassium loss throughout bed rest. During bed rest the controls consistently averaged 1-2 mEq higher in ECF potassium than the day 10 value of 47.5 mEq. Their elevated ECF potassium level was especially evident after bed rest, averaging 5 mEq more than the day 10 value. The corrected urinary excretion revealed a very large and progressive loss of potassium (152 mEq). During recovery, both groups registered a relatively constant level which was equal to the output during the previous bed rest period.

As would be expected from the observation of the serum levels, chloride content of the ECF was lower in both groups during bed rest than pre-bed rest, with the exercise group decreasing approximately 50 mEq and the controls, 25 mEq. After bed rest, both groups continued to manifest a lower concentration. As mentioned previously, these changes may be relative to movements of free water and, hence, may be manifestations of changes in the concentration of ECF contents.

Chloride balance in both groups showed a cumulative negative balance upon termination of bed rest. The exercise subjects were in slight positive balance on the second and fifth days of recumbency, but demonstrated a negative balance thereafter, as evidenced by a final balance of -58 mEq by the input-output method, and -94 mEq by the corrected equilibration method. At the end of bed rest, the controls had a net balance (by the two methods of calculation) of -271 and -459 mEq, respectively.

The addition of standard units (mEq) of sodium and potassium permits an estimation of one of the two principal anions in the blood (bicarbonate; the other being chloride), by the following equation:

$$\text{sodium} + \text{potassium} - \text{chloride} = \text{bicarbonate}$$

Estimated bicarbonate values from the above formula are given in Table 3.10. On day 12 estimated bicarbonate was 611 mEq for the exercise group and 580 mEq for the control group, or an increase over day 10 values of 103 and 73 mEq, respectively. The exercise subjects had returned to essentially the equilibration value of 508 mEq by the end of bed rest (day 19) and remained fairly constant thereafter. Conversely, the controls had elevated levels throughout bed rest, a trend that persisted through post-bed rest day 23, but reverted to the pre-bed rest level on the final day of the recovery period.

SODIUM EXCHANGE

Expt Days	Urine (Bld)	Serum conc mEq/L	ECF mEq exch	ECF bal	Diet mEq/day	Urine mEq/day	Input output bal	cum bal
1	(1)	140.1	1891		286	184		
5	(5)	141.5	1910		286	303 (229)		
9	(10)	136.5	1840		286	279	+ 7	
11	(12)	139.5	1880	+40	236	308	- 72	- 72
14	(15)	138.7	1870	+30	236	219	+ 18	- 34
16(No Bld)					236	270	- 43	- 97 (-114)
18	(19)	134.7	1815	-25	236	233	+ 3	- 94
20	(21)	134.9	1820	-20		133		
23	(23)	133.5	1800	-40		163		
26	(27)	132.3	1788	-52		160		
1	(1)	140.4	1895		286	210		
5	(5)	140.2	1851		286	254 (172)		
9	(10)	134.7	1777		286	260	+ 26	
11	(12)	137.6	1816	+39	198	302	-104	-104
14	(15)	137.9	1823	+46	198	216	- 18	-122
16(No Bld)					193	203	- 5	-127 (-244)
18	(19)	136.1	1800	+23	198	211	- 13	-140
20	(21)	134.4	1774	- 3		94		
23	(23)	135.1	1792	+15		173		
26	(27)	132.0	1745	-22		94		

POTASSIUM EXCHANGE

Expt Days	Urine (Bld)	Serum conc mEq/L	ECF mEq exch	ECF bal	Diet mEq/day	Urine mEq/day	Corr bal	cum corr bal
1	(1)	3.9	53		126	88		
5	(5)	4.1	55		126	92 (53)		
9	(10)	3.52	47.5		126	77		
11	(12)	3.90	52.6	+5.1	102	58	- 5	- 5
14	(15)	3.42	46.2	-1.3	102	68	-15	- 20
16(No Bld)					102	77	-24	- 44
18	(19)	3.46	46.6	-0.9	102	66	-13	- 57
20	(21)	3.78	51.0	+2.5		64		
23	(23)	3.77	50.9	+3.4		42		
26	(27)	3.69	49.7	+2.2		46		
1	(1)	3.9	52		126	77		
5	(5)	4.1	54		126	69 (20)		
9	(10)	3.60	47.5		126	62		
11	(12)	3.65	48.4	+0.9	84	46	-26	- 26
14	(15)	3.80	50.2	+2.7	84	67	-47	- 73
16(No Bld)					84	60	-40	-113
18	(19)	3.73	48.3	+0.8	84	59	-39	-152
20	(21)	3.84	50.7	+3.2		56		
23	(23)	4.17	55.1	+7.5		63		
26	(27)	3.97	52.6	+5.0		51		

CHLORIDE EXCHANGE

Expt Days	Urine (Bld)	Serum conc mEq/L	ECF mEq exch	ECF bal	Diet mEq/day	Urine mEq/day	Input output bal	cum bal
1	(1)	103.1	1391		290	178.9		
5	(5)	105.5	1418		290	311.3 (203)		
9	(10)	102.1	1380		290	281	+ 9	
11	(12)	98.1	1322	-58	212	285	- 63	- 63
14	(15)	99.5	1340	-40	212	207	+ 5	- 58
16(No Bld)					212	260	- 48	-106 (-177)
18	(19)	98.9	1333	-47	212	237	- 25	-131
20	(21)	100.9	1353	-27		186		
23	(23)	100.6	1351	-29		161		
26	(27)	99.0	1336	-44		174		
1	(1)	103.4	1365		290	242.7		
5	(5)	103.1	1361		290	272.5 (103)		
9	(10)	99.8	1318		290	243	+ 47	
11	(12)	97.9	1292	-26	150	273	-123	-123
14	(15)	98.0	1294	-24	150	211	- 61	-184
16(No Bld)					150	186	- 36	-220 (-459)
18	(19)	98.0	1294	-24	150	201	- 51	-271
20	(21)	98.3	1297	-21		100		
23	(23)	100.3	1321	+ 3		141		
26	(27)	98.0	1294	-24		104		

TABLE 3.9. ABSOLUTE AND DERIVED VALUES FOR ANALYSIS OF ELECTROLYTE METABOLISM. (See text.)

Day	1	5	10	12	15	19	21	23	27
Exercisers	533	547	508	611	576	529	518	500	502
Controls	582	544	507	580	579	554	633	526	504

TABLE 3.10. SERUM BICARBONATE LEVELS ESTIMATED FROM SODIUM, POTASSIUM, AND CHLORIDE. The values are expressed as total mEq in the extracellular fluid (ECF), derived by assuming an ECF volume of 13.5 L and 13.2 L in exercise and control subjects, respectively.

An assessment of total solute balance was made by combining all of the measured urinary electrolytes. In Appendix I, this balance is compared with osmotic excretion. The table below summarizes these values, and as in Table 3.9, the corrected day 9 value and the cumulative balance on day 18, appear in parenthesis. The cumulative balance was determined by the method employed in the calculation of potassium balance, as described previously in this section.

Both groups revealed an elevated output of electrolytes relative to the corrected day 9 value and, except for a small increment due to an increased chloride output on day 16 in the exercise group, both decreased in output after day 11. The reduced excretion on day 20, which as previously mentioned, was due to sodium and chloride retention, was 67% of the day 11 value in the exercise group and 40% of the day 11 value for the controls.

Day	1	5	9	11	14	16	18	20	23	26
			(485)				(-348)			
Exercisers	451	706	637	651	494	607	536	383	366	380
			(295)				(-816)			
Controls	530	596	565	621	494	449	471	250	377	249

TABLE 3.11. TOTAL ELECTROLYTE EXCRETION. Sodium, potassium, and chloride were added for each day. The corrected day 9 value appears above the measured absolute value in order to compare the two periods, pre-bed rest and bed rest, during which there were different dietary intakes of the electrolytes. The cumulative corrected balance appears in parenthesis above the excretion value for day 18.

Experimental Group	Day 10	11	12	13	14	15	16	17	18	19	20	21	23	27
Exercisers	.264	.264	.259	.249	.260	.258	.245	.250	.256	.243	.263	.262	.277	.255
Controls	.285	.278	.269	.261	.267	.252	.255	.261	.243	.246	.253	.269	.262	.255

TABLE 3.12. BASAL OXYGEN CONSUMPTION (L/MIN). Basal metabolism was taken at 0700 daily during bed rest (days 11-19) and on the first day of recovery before ambulation (day 20). Day 10 served as a pre-bed rest baseline reference value and measurements were also taken on days 21, 23, and 27 during recovery.

Respiratory Metabolism

The exercise group's mean basal oxygen consumption showed a general trend downward during bed rest (see Table 3.12). However, on days 14 and 15 (mid-bed rest), there was a transitory rebound followed by another decline through day 19. Although the three basal oxygen consumption observations during post-bed rest were somewhat variable for the exercisers, they were definitely higher than most bed rest observations. The control subjects showed a more uniform and consistent drop in basal oxygen consumption during bed rest, followed by an immediate rise upon termination of bed rest.

Basal pulmonary ventilation for the exercise group was variable between days 10 and 18 (from 6.043 to 6.354 L), at which time a definite decline was noted. However, by day 20 the basal ventilation had nearly returned to the pre-bed rest value of 6.197 L observed on day 10 and remained relatively unchanged on days 21 and 23. A comparable pattern was observed for the non-exercising controls. Respiratory rate, although variable during bed rest, tended to decline in the exercise group. No clear pattern was observed in the control subjects.

In the exercisers, the percent of true oxygen (or the number of liters of oxygen utilized per 100 liters of ventilated air) showed an immediate drop from 4.30 to 4.17 upon initiation of bed rest, but was followed by a tendency toward stabilization through day 17. An increase to 4.35 was observed on day 18, followed by a reduction to 4.26 and 4.17 on days 19 and 20, respectively. Upon termination of bed rest, the percent true oxygen trend reversed and remained elevated over the pre-bed rest value throughout recovery. The control group demonstrated a sharper decrement in the first days of bed rest (from 4.40 on day 10 to 4.12 on day 13) and continued to decline slowly throughout bed rest, reaching a value of 3.90 on day 20. There was an immediate rise to 4.20 on day 21 in the controls, an apparent peak value that remained virtually the same on days 23 and 27.

During bed rest and recovery, the exercisers' respiratory quotient (RQ) tended to vary rather closely about the day 10 pre-bed rest value of 0.81, although it was clearly higher on day 16 (0.88) and lower on day 27 (0.73). The control group showed a nearly constant RQ of 0.79 on day 10 and during the first three days of bed rest. There was a definite rise in their RQ after day 12 during the remainder of bed rest, although there was some variability. Immediately following bed rest, the controls demonstrated a drop in RQ to near pre-bed rest values.

On the first evening following bed rest, the resting oxygen consumption was lower than pre-bed rest values in both the exercise and control groups. Both groups then returned to near pre-bed rest values on days 22 and 26. The evening resting oxygen consumption averaged approximately 30% higher than the corresponding basal values in both groups.

Resting pulmonary ventilation in the exercise group did not change appreciably, whereas the controls showed a definite decline during bed rest, followed by a return to pre-bed rest values on days 22 and 26. The evening pulmonary ventilation values also averaged approximately 30% higher than the basal values for both groups. The exercise group's evening respiratory rate did not vary appreciably during the experiment. The controls, however, showed a slight decline on day 20 as compared to day 9. Both groups had higher respiratory rates during the evening metabolism (approximately 20 percent) than for the morning basal determinations.

Percent true oxygen values secured during the evening metabolisms were generally only slightly lower than the basal values obtained on the following morning. The mean values for both the exercisers and controls remained relatively unchanged during the experiment. Evening metabolism respiratory quotients (RQ) tended to be slightly higher than corresponding basal values, but otherwise failed to show any distinct pattern throughout the experiment.

Day	5	10	11	12	13	14	15	16	17	18	19	20	21	23	27
Exercisers	51.5	50.5	54.8	50.5	48.0	49.3	49.3	49.7	50.7	50.0	48.0	53.5	51.0	54.2	51.0
Controls	60.0	60.0	57.3	55.5	56.8	54.5	54.8	59.5	59.8	55.5	57.0	54.2	63.8	63.5	60.3

Table 3.13. BASAL HEART RATE (BEATS/MIN). Basal heart rate was taken by palpation midway through the 10 min basal metabolism test. Subjects were in the post absorptive state, with no other testing protocol preceding.

The data in Table 3.13 reveal that the basal heart rate for the exercise group was consistently lower than that of the controls. The observations for days 5 and 10 (pre-bed rest) show close agreement for each group. The exercisers did not demonstrate a clear trend during bed rest or recovery, as their mean values for these periods varied rather closely about their pre-bed rest observations. The controls, however, demonstrated a general decline during the first five days of bed rest, which was followed by a transitory rebound on days 16 and 17 and another decline during the last three days of bed rest. Basal heart rate observations for the controls during the recovery period showed an immediate, rather dramatic, increase above pre-bed rest values on days 21 and 23, followed by a fall to pre-bed rest levels on day 27.

Anthropometric Data

Bed rest effects on body composition, as estimated by total body potassium count, underwater immersion and skinfold calipers, and their relationships are summarized in Table 3.14. Total body potassium (K_{40}) was measured in vivo by a one hour count in a shielded chamber prior to the injection of radioactive isotopes on day 5 of the equilibration period. The exercise group averaged 199.5 gm of potassium, compared to 187.8 gm for the controls. After the subjects had been injected with isotopes for related measurements, repeat determinations were made on day 10 and yielded mean values of 163.8 and 172.0 gm for the exercisers and controls, respectively. Although there was some individual variability in the K_{40} results, it would appear that both groups lost lean body mass during bed rest. The control group's mean loss was more than twice that of the exercisers' (-11.3 and 4.8 gm, respectively). Both groups reversed their bed rest K_{40} loss following their return to six days of normal ambulatory activity during the recovery period, regaining 7.5 and 2.3 gm of their loss, respectively.

	Body Weight (kg)	K_{40} (gm)	LBM (kg)*	%Body Fat*	%Body Fat**
Exercise Group					
Day 9	69.78	164	61.04	12.85	11.33
Day 20	69.66	159	60.45	13.25	10.90
Difference	0.12	5	0.59	+ 0.40	0.43
Percent Change from Day 9	0.17	3.05	0.97	---	---
Control Group					
Day 9	69.58	172	59.71	13.93	11.75
Day 20	68.82	161	58.21	15.23	11.38
Difference	0.76	11	1.50	+ 1.30	0.37
Percent Change from Day 9	1.09	6.40	2.51	---	---

TABLE 3.14. BODY COMPOSITION. Pre-bed rest measurements were taken after 8 days of dietary equilibration with a low residue diet of fixed caloric and water intake. Post-bed rest values were determined on the first day of recovery before ambulatory activities began, (All measurements were taken between 10:00-11:45 a.m. in the post-absorptive state.) Total body potassium (K_{40}) was determined by scintillation counter, while percent lean body mass (LBM) and body fat were determined by water immersion densitometry (*), while body fat was also estimated by skinfold calipers (**).

Both groups lost lean body mass, as determined by underwater immersion, during bed rest, with that of the non-exercising controls amounting to approximately 1.5 kg, while that of the exercisers was approximately 0.6 kg. Thus, comparison between total body potassium (K_{40}) and water immersion LBM changes during bed rest reveals agreement in direction, although the former yielded approximately twice the magnitude of change (expressed as percent).

The percent of body weight estimated as fat from the underwater immersion data rose only slightly in the exercisers during bed rest (0.40), but was quite apparent in the control group (1.30). In contrast, percent of body weight estimated as fat by the skin-fold caliper technique revealed a slight reduction in seven of the eight subjects following bed rest, with mean values of 0.43 and 0.38 percent in the exercise and the control group, respectively. A small but measurable increase over immediate post-bed rest values for this parameter was noted on day 26 at the end of the recovery period.

Chest and waist circumference values,which are included in Appendix III of this Part, were variable, with no clear pattern evidenced in either group. Other body circumference parameters and strength data are summarized in Table 3.15. It can be seen that both groups demonstrated a very small increase in upper arm and calf circumferences during bed rest, with no appreciable change during the recovery period. The controls showed a drop of 1.23 cm in thigh circumference during bed rest while the exercisers demonstrated a much smaller reduction (0.20 cm).

Grip strength, strangely, was found to decline slightly with bed rest in the exercisers (2.93 lbs), while the controls showed a measurable increase (9.37 lbs). Day 27 recovery grip strength values for both groups were slightly lower than the immediate post-bed rest day 20 values. Mean knee extension strength did not change appreciably in the exercisers during bed rest (increasing 2.10 lbs),but increased substantially (12.90 lbs) over the pre-bed rest value on day 26. The non-exercising controls showed a marked drop in knee extension strength during bed rest (14.37 lbs), but by the end of recovery (day 26) they surpassed their pre-bed rest level. Plantar flexion strength increased progressively, and rather dramatically, in both groups throughout the experiment, thus suggesting a possible "learning" effect.

Variable	Exercise Group's Means			Control Group's Means		
	Day 9	Day 20	Day 26	Day 9	Day 20	Day 26
Upper arm circumference	25.93	26.10	26.00	26.18	26.23	26.33
Calf circumference	35.98	35.60	36.45	33.95	33.80	33.68
Thigh circumference	49.55	49.35	50.18	50.98	49.75	49.93
Grip strength	121.83	118.90	115.49	107.50	116.87	115.77
Knee extension strength	177.50	179.60	192.50	161.70	147.33	170.42
Plantar flexion strength	264.17	279.58	306.25	221.67	249.75	265.84

TABLE 3.15. MEAN LIMB CIRCUMFERENCE AND STRENGTH VALUES. Limb circumferences were measured with the muscles in a relaxed state by means of a steel tape graduated to the nearest 1/10 cm. Only one measurement was taken on the days specified. Strength scores were recorded as the best of three trials in lbs.

	Vital Capacity (liters)				Residual Volume (liters)
Subject #	Day 0	Day 9	Day 20	Day 26	
1	5.69	5.85	5.97	5.81	0.927
3	3.91	4.08	4.09	3.92	0.784
5	4.66	4.52	4.42	4.61	0.779
7	5.90	5.86	5.75	5.90	1.080
Exercise $\bar{x}$	5.04	5.08	5.06	5.06	0.893
2	5.11	5.21	5.11	5.11	1.607
4	4.56	5.04	4.75	5.00	0.865
6	4.15	4.18	4.02	4.11	1.009
8	5.74	5.64	5.45	5.51	1.131
Control $\bar{x}$	4.89	5.02	4.83	4.93	1.152

TABLE 3.16. RESPIRATORY VOLUMES. Vital capacity was determined before the experiment (day 0), just prior to bed rest (day 9), on the first day of recovery (day 20), and at the end of recovery (day 26). All measurements were taken in the post-absorptive state. Residual volume was determined only once (at the end of the experiment).

Table 3.16 contains individual subject and group data for vital capacity and residual lung volume determinations. It can be seen that vital capacity did not change appreciably in the exercise group, while a 200 ml drop from the pre-bed rest value was observed on day 20 in the controls. They regained half (approximately 100 ml) of this loss by the sixth day of recovery (day 26).

Residual lung volume was measured only once (at the end of the experiment). The mean residual volume for the exercise group was substantially less (0.893 L) than the non-exercising controls (1.152 L), which is somewhat surprising in view of their nearly equal post-bed rest vital capacities of 5.06 and 4.93 L, respectively.

Physiological Response to Exercise

The dynamic response to a 30 minute bout of work was studied before, during, and after bed rest in the exercise group and during pre- and post-bed rest periods in the control group. The physiological parameters measured included those necessary for determining renal clearances, electrolyte excretion, and respiratory metabolism. Measurements were made on days 10, 12, 15, 19, 21 and 27, which have been referred to previously in the text as renal function test days. Blood constituents were not analyzed on these days due to the distortion of these values by the large water load. Since the urine volume was measured during the tests, it was possible to eliminate the dilution effect on urinary electrolytes by expressing the values in units of time, rather than in units of volume (i.e., μEq/min, as opposed to mEq/L).

Exercise Renal Function

The exercise group's RPF during exercise reflected the same response pattern as the resting RPF, ie., varying in phase with the resting changes and differing only in the absolute level of response. If RPF during exercise is expressed as the percent of resting levels, it can be seen that in only a few instances did the percent of change during

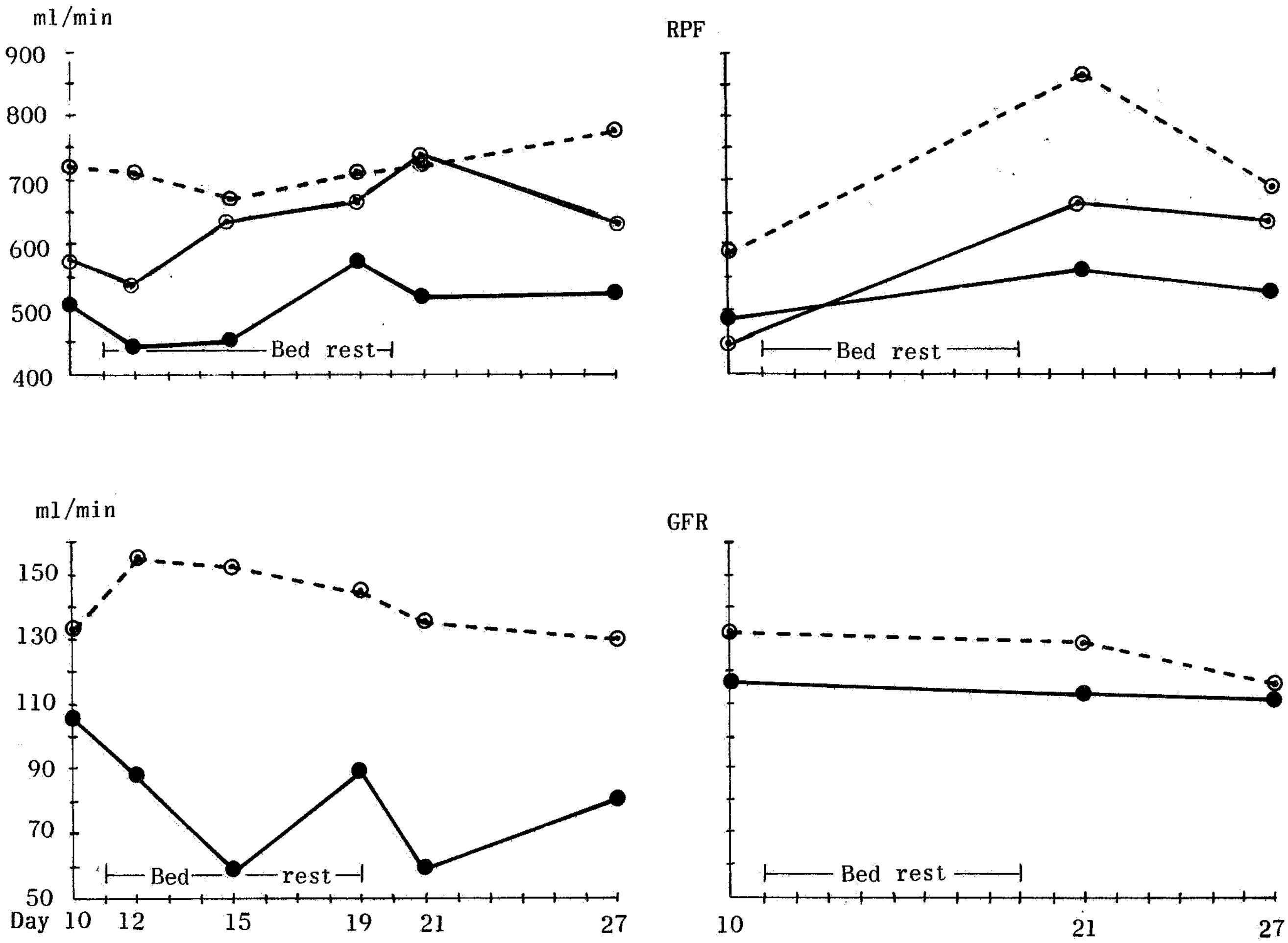


FIGURE 3.4. RENAL CLEARANCES BEFORE, DURING, AND AFTER 30 MINUTES EXERCISE. Two resting clearances were taken before exercise, one during exercise, and two after exercise. GFR was measured once before and once during exercise by the endogenous creatinine method. Exercise subjects performed the exercise bout during the renal function tests; controls exercised only on pre- and post-bed rest renal function test days (⊙ - - - ⊙ pre-exercise clearances; ●——● clearances during exercise; ○——○ post-exercise clearances).

bed rest vary from pre-bed rest measurements (see Figure 3.4). The exercise RPF was 67 $\pm$ 4% of resting RPF on days 10, 12, 15, and 27. On day 19 the value was 82% of resting, indicating a smaller depression of RPF during exercise. Three of the four resting values on day 21 were disregarded in the exercise group (subjects 1, 5, and 7) for reasons mentioned earlier (see section on renal function); the value for subject 3 on day 21 was 63% of resting RPF. The control subjects demonstrated a depressed RPF during exercise amounting to 77 $\pm$ 2% of resting on days 10 and 27 and 62% on day 21.

On certain days, the exercise subjects revealed a very marked change in GFR in response to exercise. On day 10 the depression of GFR from resting values of 133 was 30 ml/min (78% of resting) in exercisers. As the experiment progressed the degree of depression, although variable, was always of a larger magnitude than 78% of the resting value observed on day 10. On days 15 and 21, the depression was extremely large; with

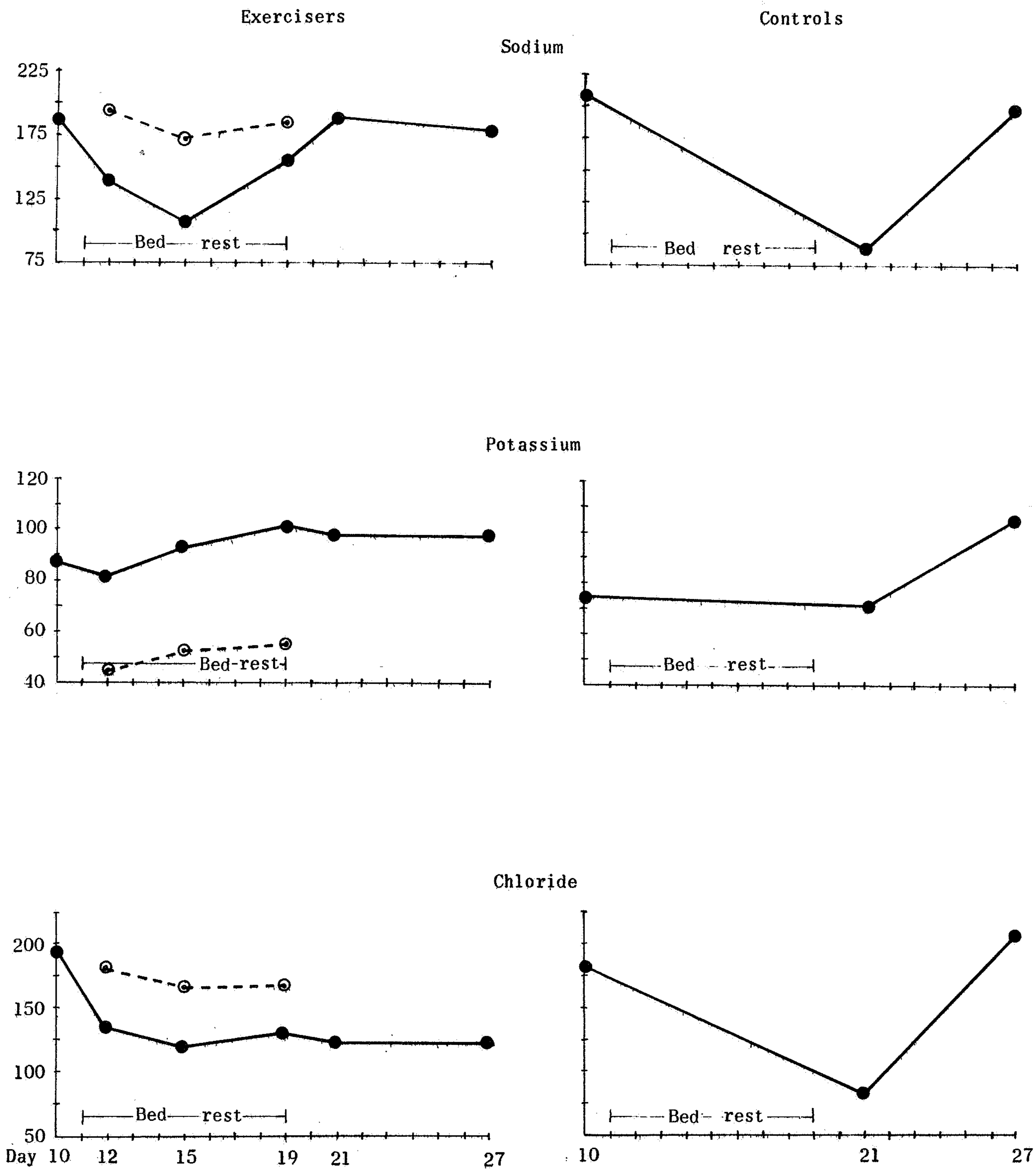


FIGURE 3.5. ELECTROLYTE EXCRETION DURING REST AND EXERCISE. Urine specimens were collected the end of exercise and represented the total urine production during the 30 minutes of work. Since resting urine levels were assumed to be constant during bed rest, pre-exercise urines were represented by 24 hour pooled urine samples. Pre-exercise urine samples were not measured during the ambulatory periods (⊙- - - -⊙ 24 hour urine excretion; ●——● urine collected at the end of exercise).

exercise values of 55 ml/min, as compared to the resting values of 150 and 132 ml/min, or 35% and 41% of resting, respectively. On either day, three of four subjects had a depression of this order, with the single exception being a different subject in each instance. On days 12, 19, and 27, resting GFR was 142 ± 10 ml/min, and was depressed to 84 ± 6 ml/min during exercise. The resting value on day 10 for the controls was 131 ml/min and during exercise was depressed to 108 ml/min, or 82%. On days 21 and 27, GFR was 128 and 118 ml/min and was depressed to 113 ml/min on both days, or 88% and 96% of resting values, respectively. Hence, there was a much smaller depression of GFR during exercise in the controls on days 21 and 27.

Sodium excretion during exercise was depressed during bed rest to varying extents in the exercise group, with the greatest depression (60% of resting) observed midway through bed rest. Pre-exercise values were not available during ambulatory periods. However, the rate of excretion during exercise was the same on the three ambulatory renal function test days (days 10, 21, and 27) in this group. The controls had an equal rate of excretion after exercise on days 10 and 27, but a greater depression on day 21. The mean value for day 21 was 98 Eq/min compared with 208 Eq/min on day 10 and 192 Eq/min on day 27.

Potassium excretion rates during exercise were consistently higher than resting rates in the exercise subjects. In addition, with the exception of day 12, all other days were increased over the day 10 exercise value of 89 Eq/min. The control subjects did not demonstrate any change in rate during exercise on renal function test days 10 or 21. On day 27, their rate of excretion during the exercise period was 102 Eq/min compared to 73 and 68 Eq/min on days 10 and 21.

The rate of chloride excretion in the exercisers fell below the pre-bed rest day 10 value of 183 Eq/min throughout bed rest and recovery, with an average of 120 ± 9 Eq/min. The chloride excretion in control subjects revealed a pattern quite similar to that for sodium excretion.

Exercise Respiratory Metabolism

Since all exercise respiratory metabolism measurements were taken during three separate time intervals (0-10, 10-20, and 20-30 min), it is prohibitive to report the mean values for all parameters. Most of the trends observed in any particular parameter were manifested in all three sampling periods; hence, only values obtained during the final period (20-30 min) are presented in this section. However, in cases where the trends observed in the first two measurement periods appear to differ from the third,

	Exercisers			Controls		
	Day 10	Day 21	Day 27	Day 10	Day 21	Day 27
Oxygen intake	1.858	1.814	1.769	1.572	1.538	1.560
Pulmonary ventilation	42.74	40.55	40.00	36.17	33.90	34.56
Respiratory rate	30.0	29.0	28.5	29.5	28.5	28.0
True oxygen percent	4.89	5.05	5.02	4.91	5.15	5.10
Respiratory quotient	0.84	0.88	0.85	0.84	0.89	0.85
Heart rate	136.25	126.50	125.50	131.75	138.50	122.50

TABLE 3.17. CIRCULATORY-RESPIRATORY RESPONSE TO SUB-MAXIMAL SUPINE BICYCLE ERGOMETER EXERCISE. Oxygen intake and pulmonary ventilation are expressed in L/min, STPD and, along with true oxygen percent and the respiratory quotient, were determined from an aliquot of the respiratory gas sample secured from 20-30 min of the exercise bout. Respiratory rate was determined between 28-29 min of the exercise bout and is expressed in breaths/min, while heart rate was measured between 29-30 min and is expressed in beats/min.

mention of this fact is made in the body of the text. Table 3.17 contains exercise respiratory metabolism data for the period 20-30 min for both groups on days 10, 21, and 27. Measurements were also made on the exercisers on days 12, 15, and 19 during bed rest. The individual values for these and all other exercise testing sessions, as well as means and standard deviations for both groups, are included in the computer print-out reproduced in Appendix III of this Part.

It can be observed in Table 3.17 that the oxygen consumption during the standardized bicycle ergometer ride was approximately 15 percent higher in the exercise group. This can be attributed primarily to the higher workloads assigned the exercisers (805 kpm/min, as compared to 744 kpm/min for the controls). The exercise group's mean oxygen consumption dropped progressively throughout bed rest,but returned to near their pre-bed rest value after 24 hours in the ambulatory state (day 21). The control group did not differ substantially from the exercise group in either magnitude of change or the pattern of response of exercise oxygen consumption on the days they were both tested.

Exercise pulmonary ventilation dropped during bed rest in the exercisers, with a similar trend evidenced by the control's mean values on days 10 and 21. The exerciser's respiratory rate tended to be variable and revealed no particular pattern for the first two measurement periods; however, the exercisers showed a slight decrease with bed rest in the last 10 minute period. The non-exercising control group had a slightly lower exercise respiratory rate on day 21 than on day 10 (pre-bed rest) and, as was the case with the exercisers, demonstrated a still lower value on day 27.

The percent true oxygen tended to increase during bed rest in the exercise group, but was followed by a slight drop during recovery. Observations in excess of the pre-bed rest value were noted in the controls on day 21, with a slight drop in their mean value noted on day 27. The exercise group's RQ was higher in bed rest (with a peak observed on day 15), whereupon a general decline toward pre-bed rest levels by the end of recovery (day 27) was observed. The controls had a higher RQ on day 21 than was observed on day 10, but by day 27 their RQ had again returned to the pre-bed rest value.

As bed rest progressed, the exercisers demonstrated a variable but clear decline in heart rate measured during both the morning and afternoon 30 minute bicycle ergometer exercise training bouts. This observation was consistent for each count made during the last minute of the three sampling periods (i.e., 9-10, 19-20, 29-30 min). Conversely, the controls had significantly higher exercise heart rates on day 21 (post-bed rest) than they did on day 10 (pre-bed rest). A sharp drop well below their day 10 value was noted during the last exercise bout of the experiment (day 27).

Appendix I: Analysis of Related Parameters

As was mentioned at the beginning of Part III, the data for a number of parameters was presented in more than one context. For example, serum and urinary electrolyte data were analyzed under their respective headings, as well as under electrolyte metabolism. In addition, it was felt that numerous other parameters presented under separate headings in Part III in order to facilitate organization, should also be compared to reveal interrelationships. The three pages of graphs together with the brief description of the graphs and the trends they depict preceding them, are intended to elucidate these relationships.

Urinary and Serum Electrolytes: Sodium, potassium, chloride, and sodium potassium ratios are shown for urine serum in Figure 3.6 . The ordinates for urinary values appear on the left and the ordinates for serum volumes on the right. The corrected urinary value for day 9 (see Part III, Electrolyte Metabolism) is included for comparison of pre-bed rest and bed rest values with the dietary changes taken into account (represented on day 9 by a solid circle).

Body Fluid Compartments and Renal Function: The top graph in Figure 3.7 shows a corrected urine volume (CUV) plotted against plasma volume (PV). The CUV was obtained by the following formula:

day 9 urine volume - [(bed rest fluid intake - pre-bed rest fluid intake) - (bed rest sweat output - sweat output pre-bed rest)]

Hence, the bed rest volumes represent changes in urine production independent of changes in water intake or sweat output. The second graph shows the sum of the urinary electrolytes (sodium, potassium, and chloride) plotted against osmotic output. The contribution of electrolytes to the total solute excretion is shown in this graph. The corrected electrolyte output for day 9 (solid circle) is included for comparison of the two periods with the changes of dietary input taken into account; reference to the difference in dietary input shows the magnitude of the negative electrolyte balance. The third graph in Figure 3.7 shows the filtration rate of plasma (GFR) plotted against the "day" urinary excretion rate. The "day" rate (previously mentioned in Part III) and the day periods (0700-2300) were shown to be the periods during which urine volume seemed to be increased during bed rest. The fourth graph shows renal plasma flow (RPF) plotted against blood volume (BV).

Filtered Load and Electrolyte Clearances: The graphs in Figure 3.8 depict the amount of the three individual electrolytes filtered on each day; that is, the filtered load (plasma concentration x GFR) and the volume of plasma which was cleared of these electrolytes, i.e., the renal clearance (urinary flow rate x urinary concentration/plasma concentration). The ordinates on the right have been adjusted so that both groups have day 9 values beginning at the same point in order to show deviations of one parameter relative to the other during bed rest and recovery (see Figure 3.3).

The trends of electrolytes exemplify the exchanges described in the section on electrolyte metabolism. Sodium increased in serum and urinary excretion levels for both groups on day 11, but generally followed a downward pattern throughout bed rest and recovery. Potassium serum levels were generally stable. Both groups demonstrated a steady decline in urinary output, except for day 11, when a distinct decrease in urinary output was observed in both groups, coupled with an increased serum potassium in the exercise group (serum of day 12 represents the blood levels at the end of the 24 hour pool of collected urine for day 11). Serum and urinary chloride dropped in the exercise subjects on day 11, whereas serum and urine had opposite trends in the control group on that day. Thereafter, the exercisers had opposite trends in these two parameters, with gradually rising serum levels and generally declining urinary excretion, whereas the controls maintained constant serum levels and decreased urinary output. Sodium/potassium ratios for serum and urine showed distinctly opposite trends in the exercise group on days 11 and 14, whereas there was no such pattern for the remainder of the 12 days of bed rest and recovery. With the exception of a very high urinary ratio on day 11, the control subjects showed a downward trend during the entire experiment. The dietary sodium/potassium ratio was maintained at 2.3 for both groups throughout the experiment.

Figure 3.7 shows the relationship between the body fluid compartment changes and renal function. The exercise subjects showed no consistent relationship between urine volume and PV during bed rest, although on days 18 and 20, when urine volume was diminished, PV had increased on the mornings of days 19 and 21 (which end the 24 hour urine collection period for days 18 and 20, respectively). The control subjects revealed a parallel relationship between urine production and PV up to day 20, when 24 hour urine increased and PV decreased. The total measured electrolytes excreted compared with osmotic excretion demonstrated a downward trend in both groups. However, on day 16, the exercisers increased excretion greatly relative to osmotic output. On that day all three of the individual electrolytes increased markedly and, in addition, serum sodium/potassium was somewhat elevated. On day 11, the controls showed a vastly increased electrolyte excretion with no such increment in total solute excretion. There was a -816 mEq total electrolyte imbalance from baseline excretion levels in the controls at the end of bed rest (see Table 3.11). With the exception of days 16 and 18, when urine flow was increased, GFR and "day" urinary flow rate had similar patterns. Thereafter, both decreased steadily. After day 11, the GFR in controls demonstrated similar patterns in these two parameters, in that compared with pre-bed rest values, both were slightly elevated during bed rest, and were depressed after bed rest. RPF and BV showed a consistent relationship during bed rest in the exercise group, and in the control group on day 19 and the two recovery days. The curves had opposite slopes on days 21 and 27 in the exercisers.

Sodium was increased in the rate of filtration and clearance on day 11 in the exercisers, but the controls had a decreased filtered load with an increased clearance. The two groups showed generally opposite slopes in the two parameters during the three remaining days of bed rest. On day 20 both groups decreased the filtered load and demonstrated a marked decrease in sodium clearance. On day 23 both groups had an increased clearance but revealed a further decreased filtered load than that observed on day 20. Potassium clearance showed a decrement on day 11 in both groups, while the filtered load increased only in the exercisers. However, the exercisers demonstrated a decreased filtered load and an increased clearance on days 14 and 16. The control subjects on these two days had increased values for both parameters. During recovery, the exercisers showed a decrement in filtration and clearance of potassium, whereas the controls showed no change. Except on day 23, when the chloride clearance of the exercisers decreased, whereas that of sodium showed a large increase, an identical pattern of sodium and chloride filtration and clearance was observed throughout the experiment in both groups. Hence, the foregoing graphic analysis of electrolyte relationships shows that sodium and chloride were apparently excreted according to a similar trend, whereas potassium showed an opposite response on day 11, and no apparent relation to sodium and chloride on the remaining days.

In order to represent the combined data of filtered loads and renal clearances numerically, the amount of the filtered load which was reabsorbed has been calculated and is shown in Table 3.18.

Day:	1	5	9	11	14	16	18	20	23
Exercisers									
Sodium	99.3	98.9	99.0	99.0	99.3	99.0	98.9	99.5	99.3
Potassium	88.4	97.9	89.0	93.3	91.2	88.9	90.9	91.3	93.8
Chloride	99.1	98.4	98.6	98.7	99.0	98.7	98.8	99.0	99.0
Controls									
Sodium	99.2	99.0	99.0	98.7	99.2	99.2	99.3	99.6	99.2
Potassium	90.1	91.1	91.2	92.9	91.7	92.5	92.4	92.2	91.4
Chloride	99.0	98.6	98.8	98.4	99.0	99.0	99.0	99.5	99.2

TABLE 3.18. PERCENT REABSORPTION OF FILTERED LOAD. The percent reabsorption was calculated by dividing the amount reabsorbed (filtered load-amount excreted) by the filtered load, and multiplying the quotient by 100 (i.e., fractional reabsorption or 1-[clearance/GFR]).

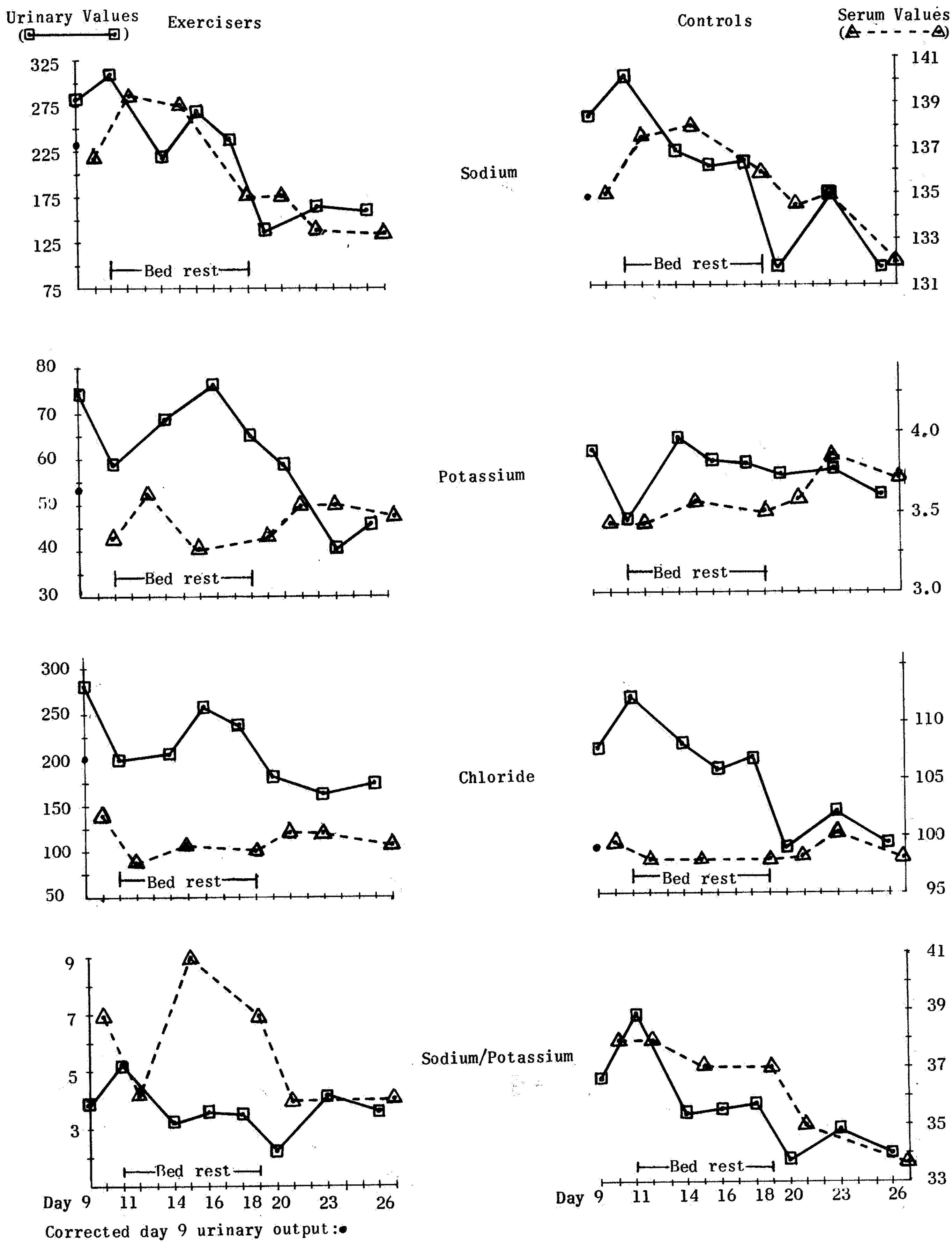


FIGURE 3.6. URINARY AND SERUM ELECTROLYTES. See text for explanation.

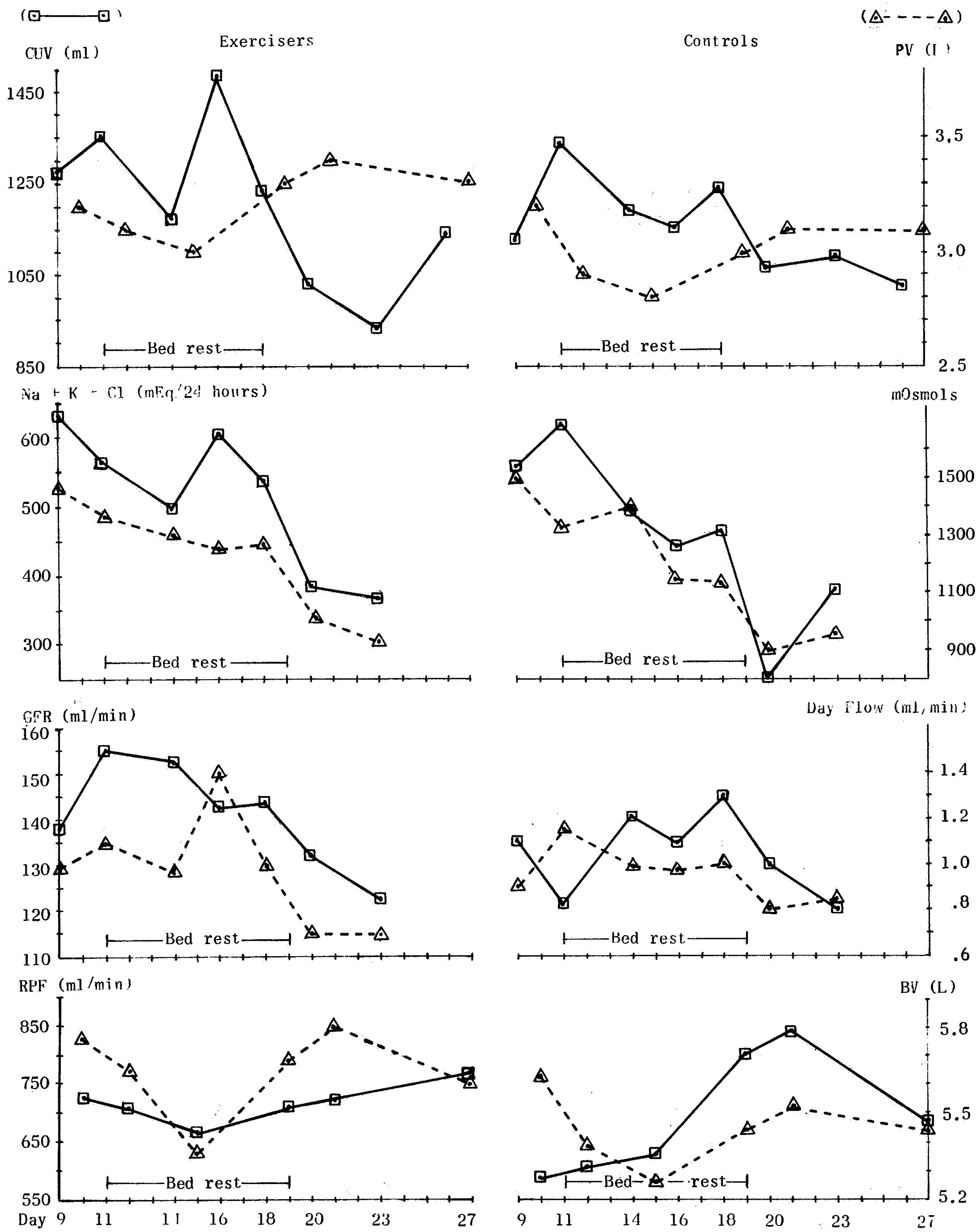


FIGURE 3.7. BODY FLUID COMPARTMENTS AND RENAL FUNCTION. See text for explanation.

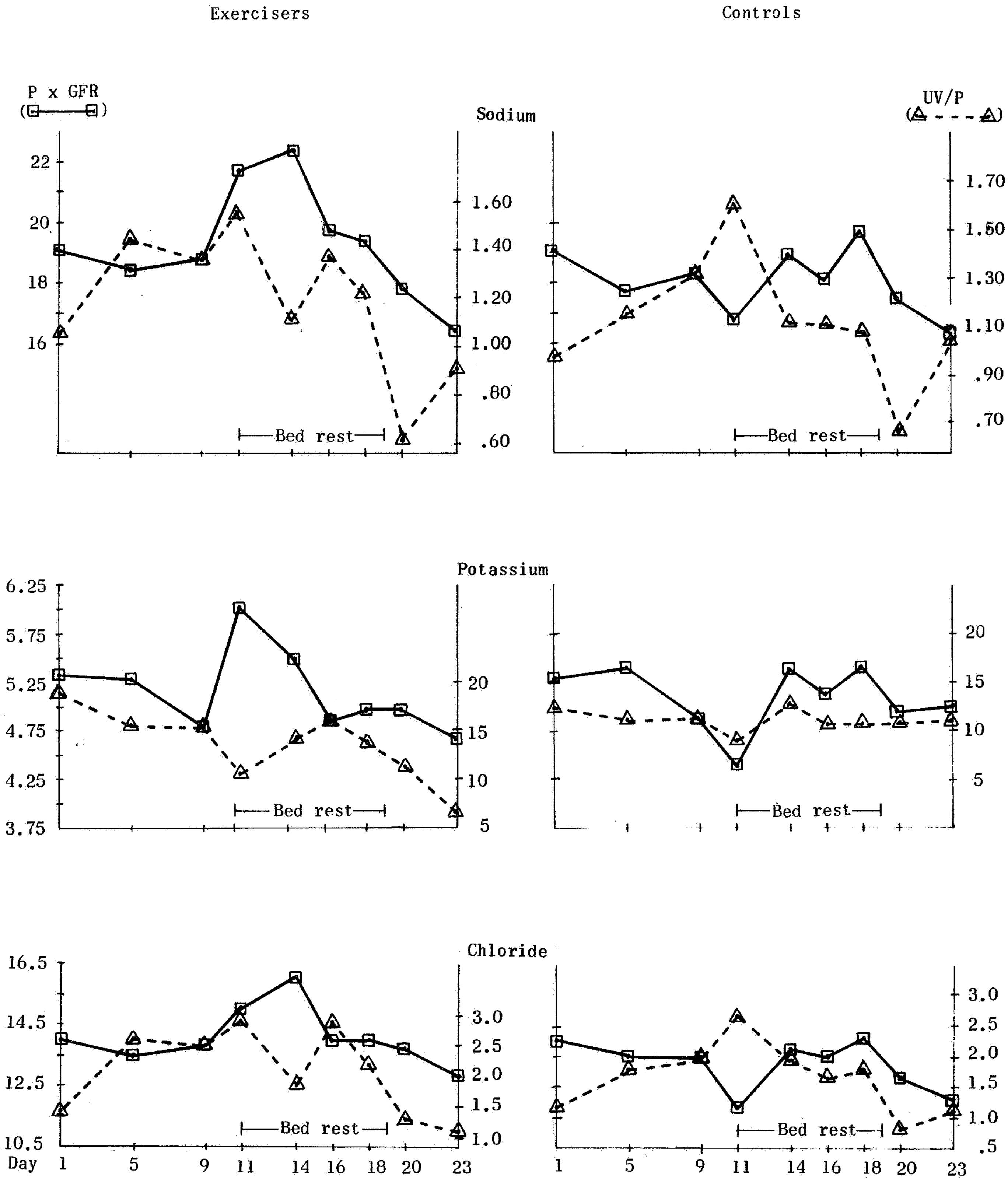
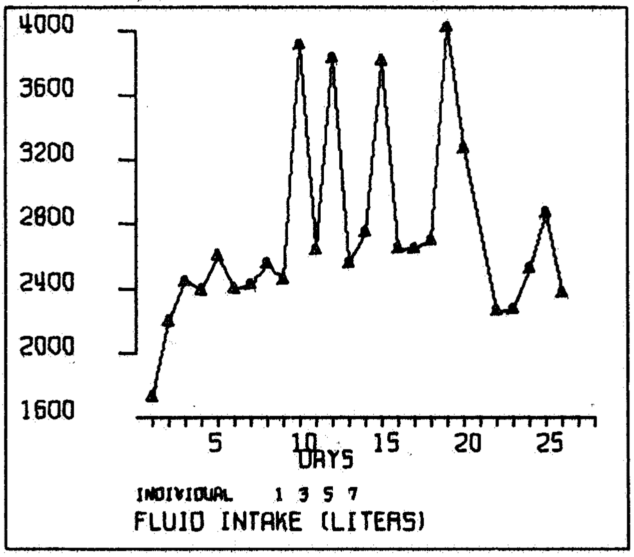
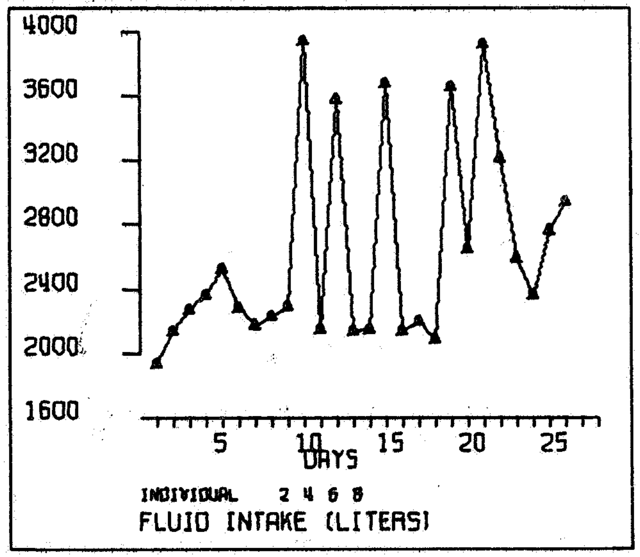


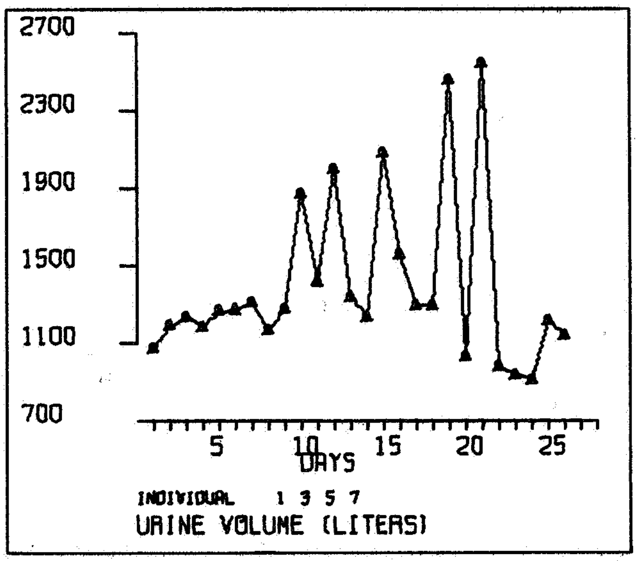
FIGURE 3.8. FILTERED LOAD AND ELECTROLYTE CLEARANCES. See text for explanation.

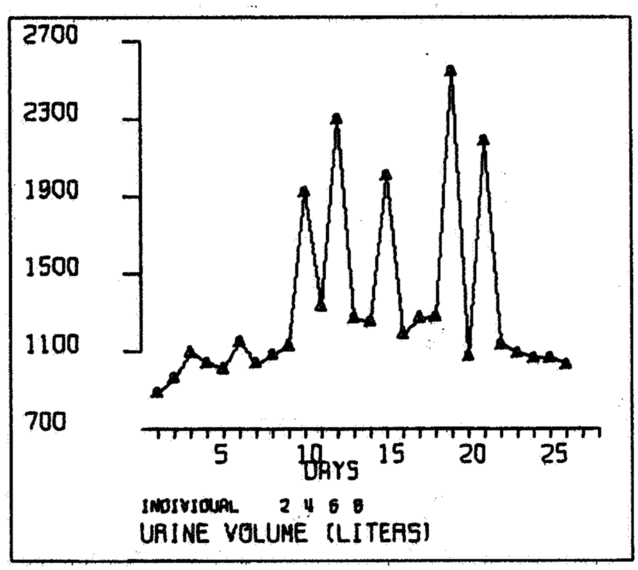
Appendix II: Computer Graphs of Each Parameter

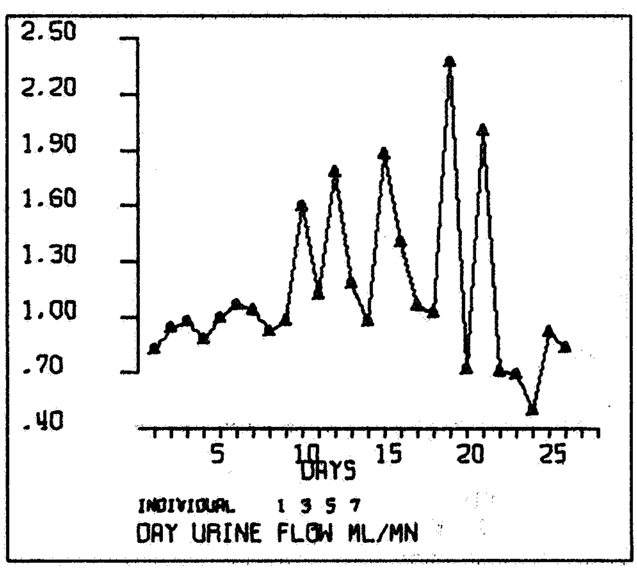
The following pages contain graphs of mean values of each parameter measured for the exercise and control groups. The order of the graphs follows that of the data collection outline given in Part I. Figures on the left side represent the data plots from the exercise group, while the corresponding parameter for control subjects appears on the right. Certain parameters were measured only in exercisers (e.g., exercise metabolism during bed rest); hence, in these cases, the space opposite the graph for exercisers remains empty. Below some of the graphs there is a notation: "*Some approximations included". This statement was programmed into the computer to recognize values that were not measured on the day indicated. In most cases the values had been measured on another day when little difference was expected (e.g., on day 8 instead of day 9). In addition, the data on blood volume and renal plasma flow for subject I was eliminated from Part III, but was marked with an asterisk and remains in the computer print-out (Appendix III) as well as in the graphs. The following list gives the order of the graphs and the pages on which they appear.


4000
3600
3200
2800
2400
2000
1600
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
FLUID INTAKE (LITERS)


4000
3600
3200
2800
2400
2000
1600
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
FLUID INTAKE (LITERS)


2700
2300
1900
1500
1100
700
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
URINE VOLUME (LITERS)


2700
2300
1900
1500
1100
700
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
URINE VOLUME (LITERS)


2.50
2.20
1.90
1.60
1.30
1.00
.70
.40
5
10
15
20
25
DAYS
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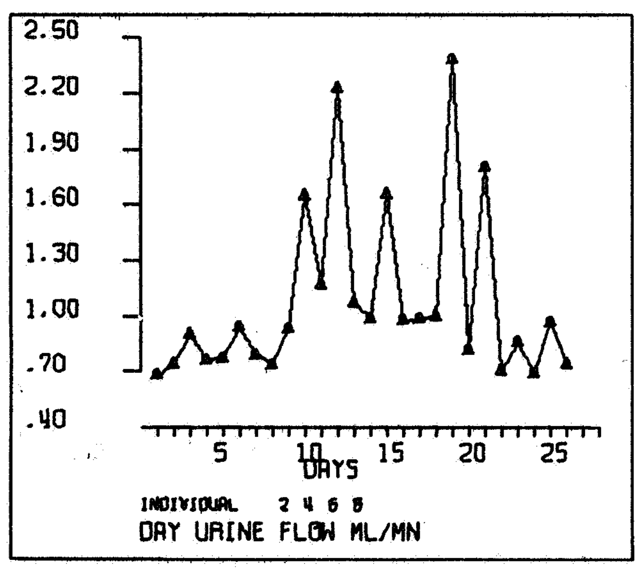
DAY URINE FLOW ML/MN


2.50
2.20
1.90
1.60
1.30
1.00
.70
.40
5
10
15
20
25
DAYS
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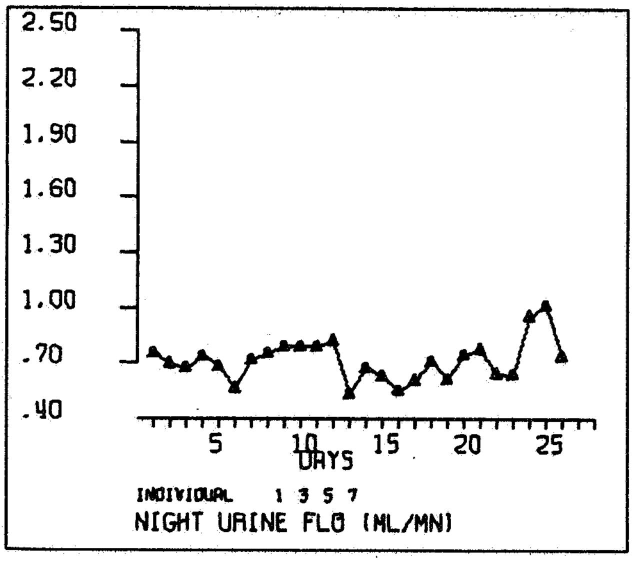
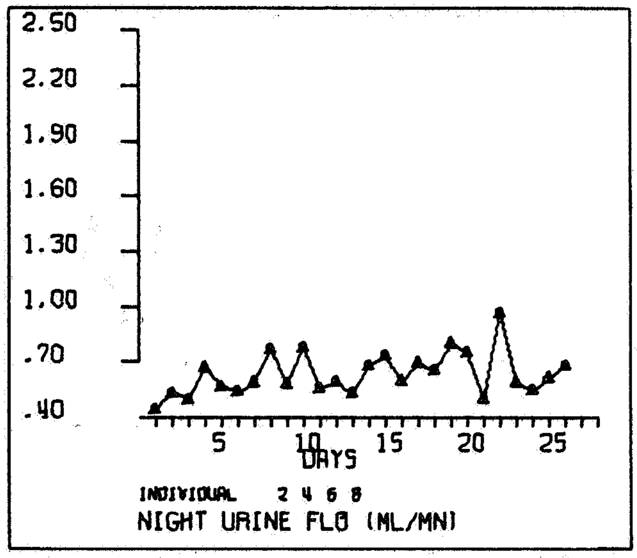
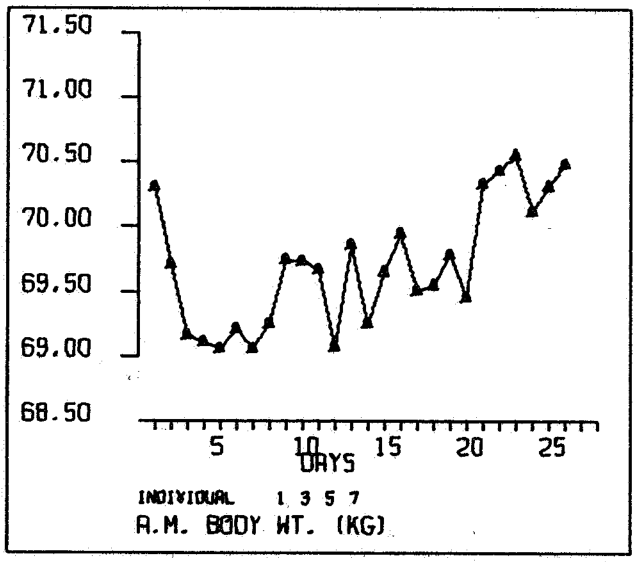
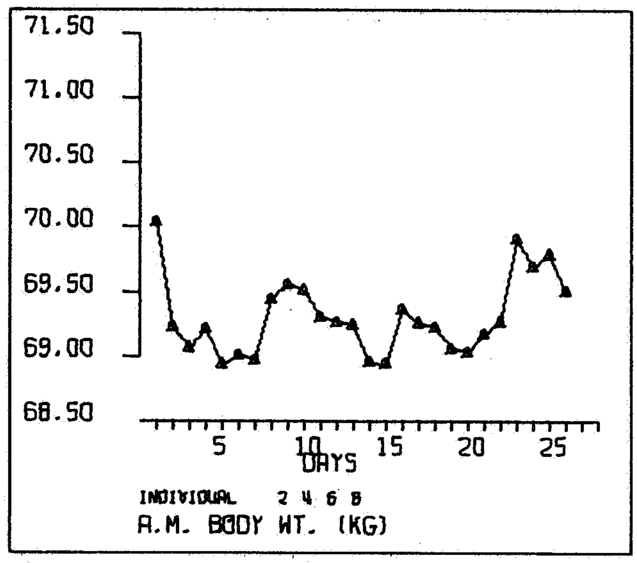
DAY URINE FLOW ML/MN


2.50
2.20
1.90
1.60
1.30
1.00
.70
.40
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
NIGHT URINE FLO (ML/MN)


2.50
2.20
1.90
1.60
1.30
1.00
.70
.40
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
NIGHT URINE FLO (ML/MN)


71.50
71.00
70.50
70.00
69.50
69.00
68.50
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
A.M. BODY WT. (KG)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71.00
70.50
70.00
69.50
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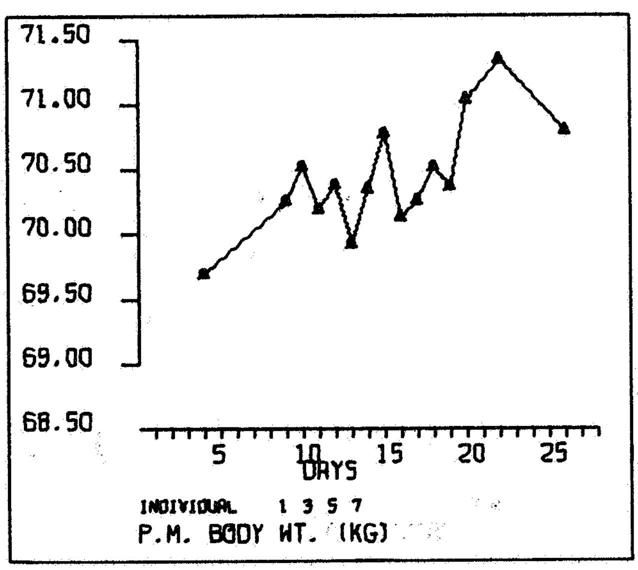
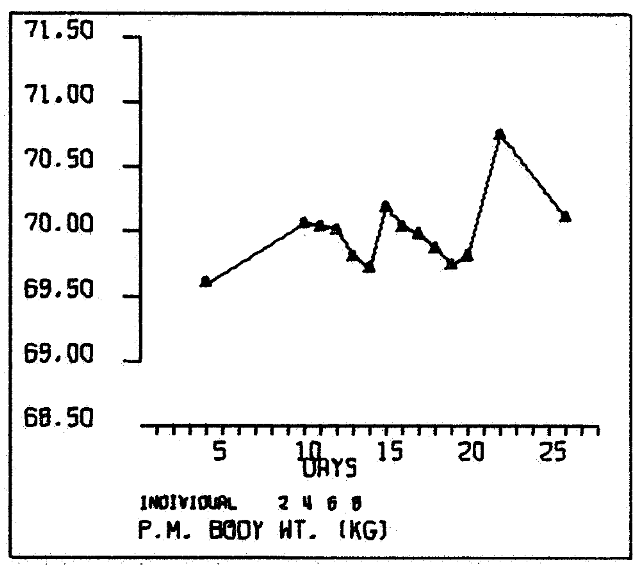
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
A.M. BODY WT. (KG)


71.50
71.00
70.50
70.00
69.50
69.00
68.50
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
P.M. BODY WT. (KG)


71.50
71.00
70.50
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69.00
68.50
5
10
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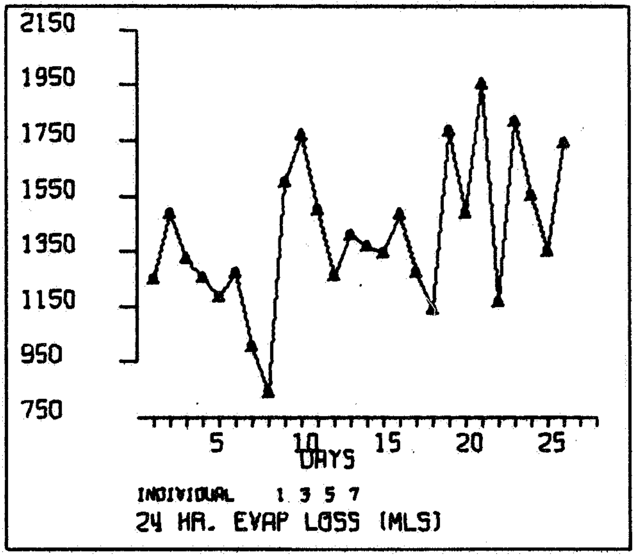
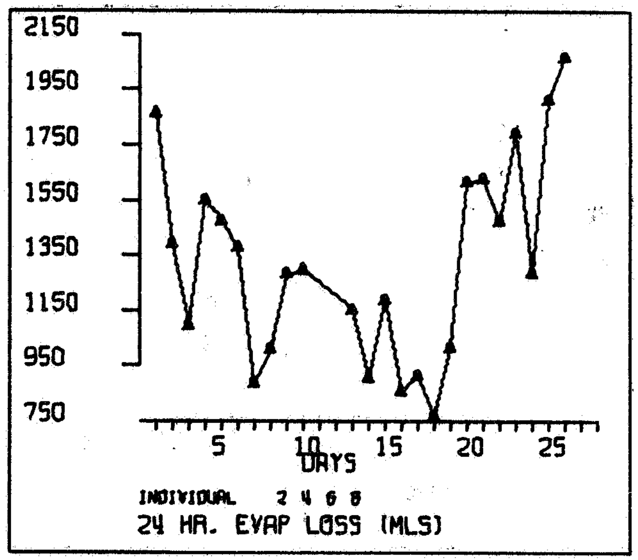
20
25
DAYS
INDIVIDUAL 2 4 6 8
P.M. BODY WT. (KG)


2150
1950
1750
1550
1350
1150
950
750
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
24 HR. EVAP LOSS (MLS)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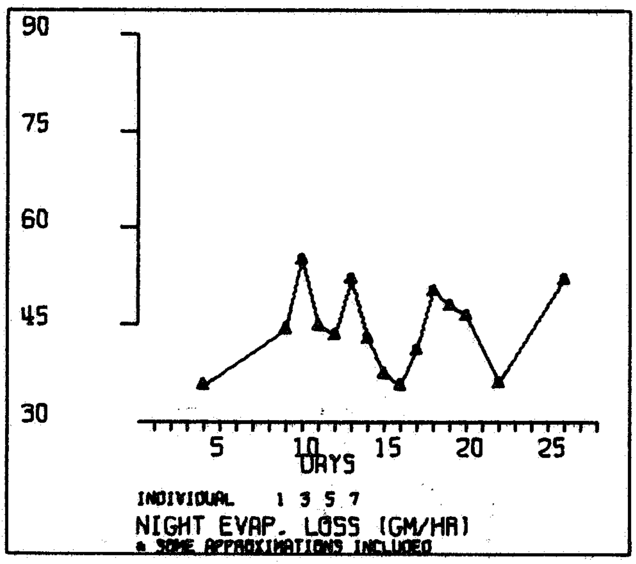
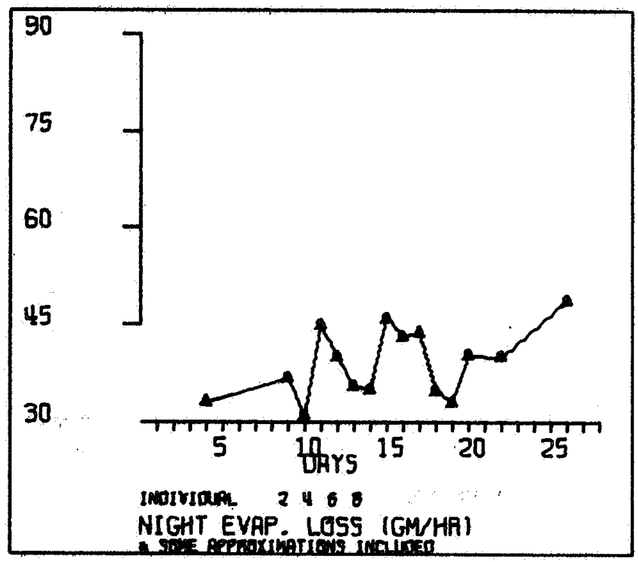
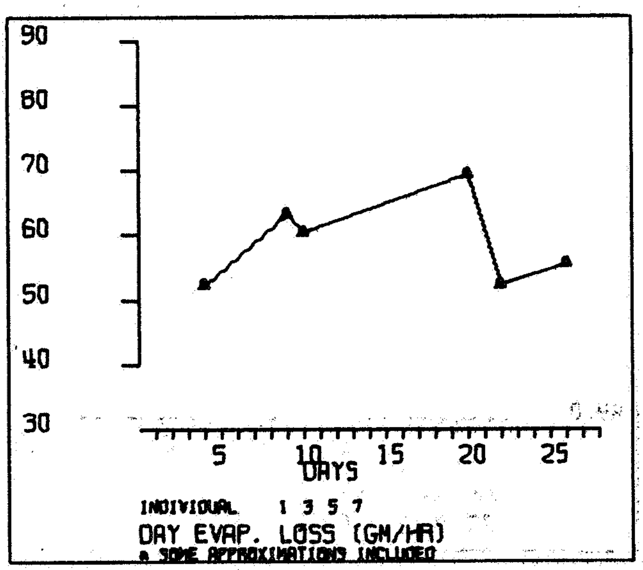
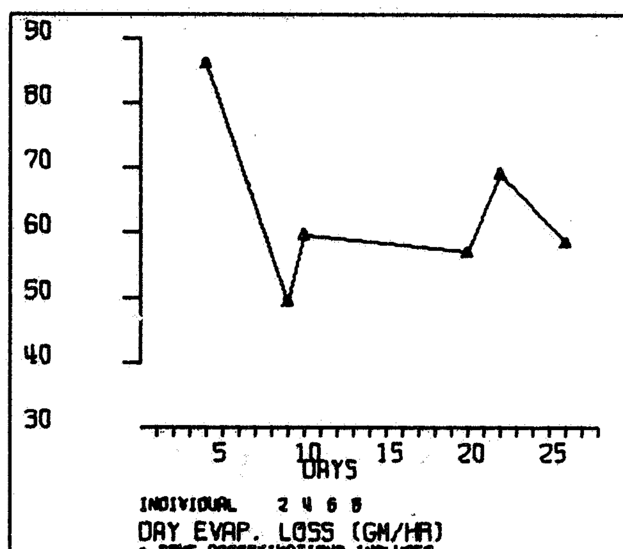
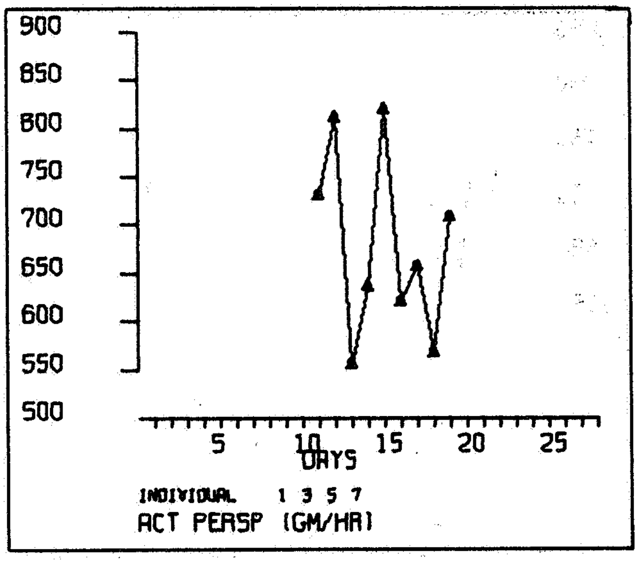
1950
1750
1550
1350
1150
950
750
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
24 HR. EVAP LOSS (MLS)


90
75
60
45
30
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
NIGHT EVAP. LOSS (GM/HR)
* SOME APPROXIMATIONS INCLUDED


90
75
60
45
30
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
NIGHT EVAP. LOSS (GM/HR)
* SOME APPROXIMATIONS INCLUDED


90
80
70
60
50
40
30
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
DAY EVAP. LOSS (GM/HR)
* SOME APPROXIMATIONS INCLUDED


90
80
70
60
50
40
30
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
DAY EVAP. LOSS (GM/HR)
* SOME APPROXIMATIONS INCLUDED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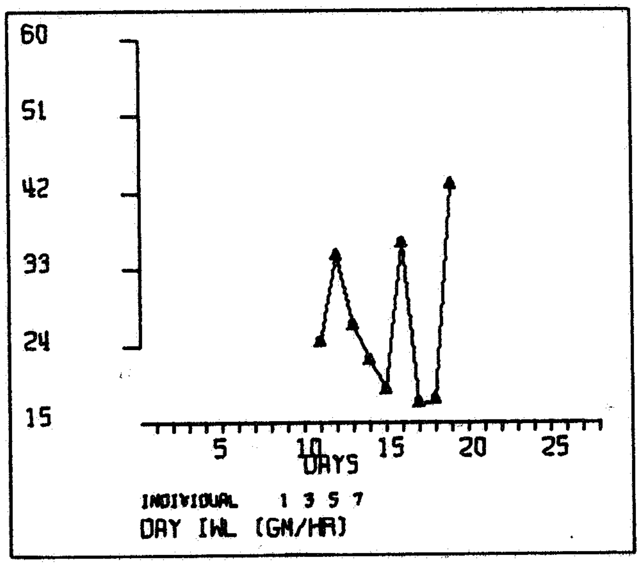
850
800
750
700
650
600
550
500
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
ACT PERSP (GM/HR)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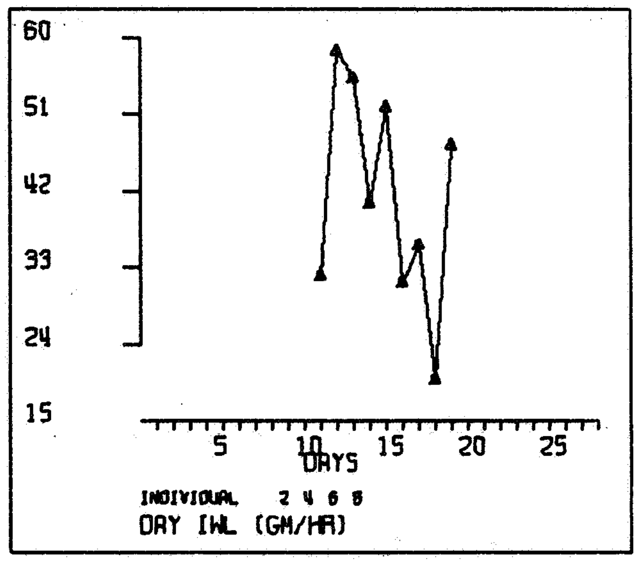
51
42
33
24
15
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
DAY IWL (GM/HR)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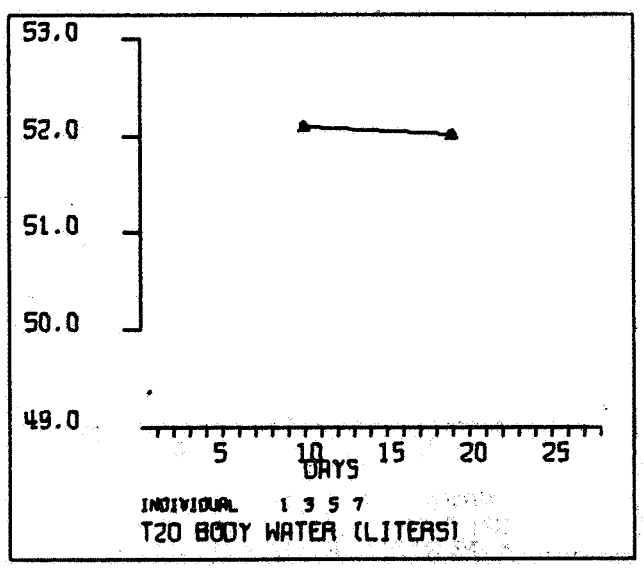
42
33
24
15
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
DAY IWL (GM/HR)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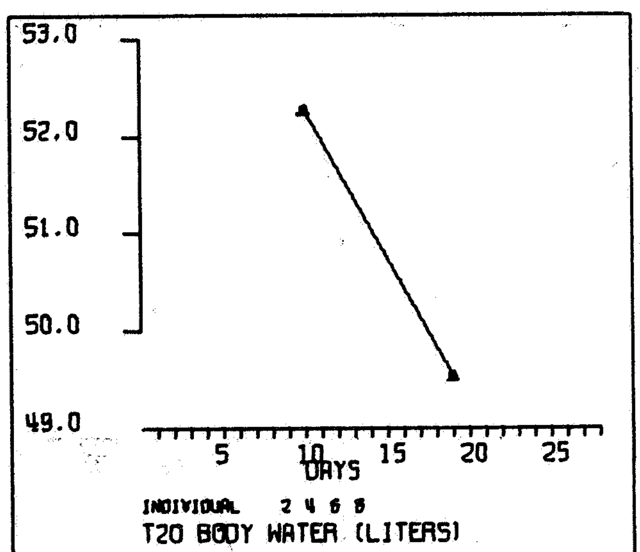
52.0
51.0
50.0
49.0
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
T20 BODY WATER (LITERS)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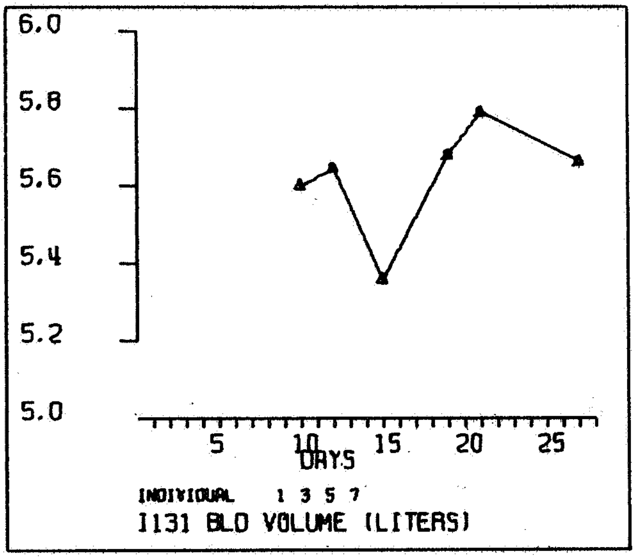
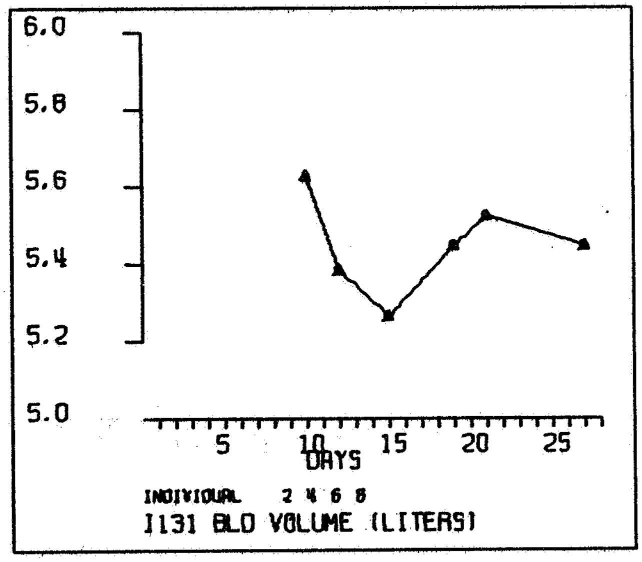
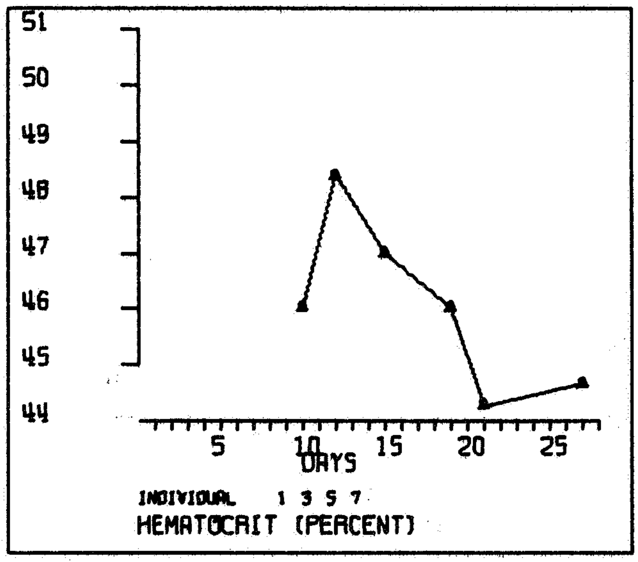
25
DAYS
INDIVIDUAL 2 4 6 8
T20 BODY WATER (LITERS)


6.0
5.8
5.6
5.4
5.2
5.0
5 10 15 20 25
DAYS
INDIVIDUAL 1 3 5 7
I131 BLD VOLUME (LITERS)


6.0
5.8
5.6
5.4
5.2
5.0
5 10 15 20 25
DAYS
INDIVIDUAL 2 4 6 8
I131 BLD VOLUME (LITERS)


51
50
49
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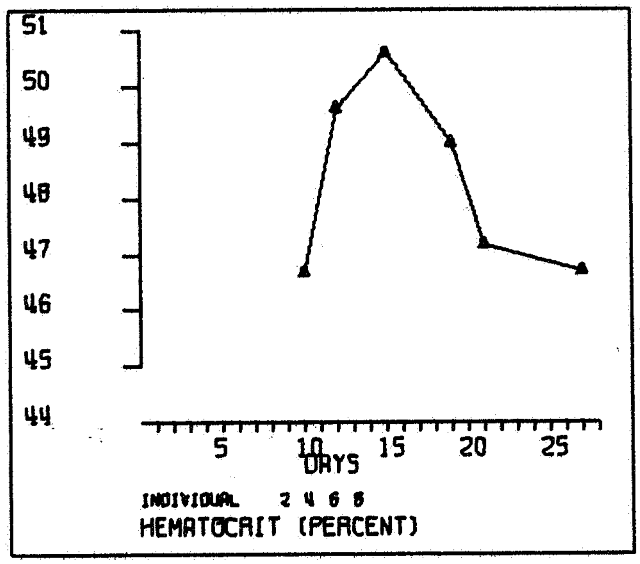
45
44
5 10 15 20 25
DAYS
INDIVIDUAL 1 3 5 7
HEMATOCRIT (PERCENT)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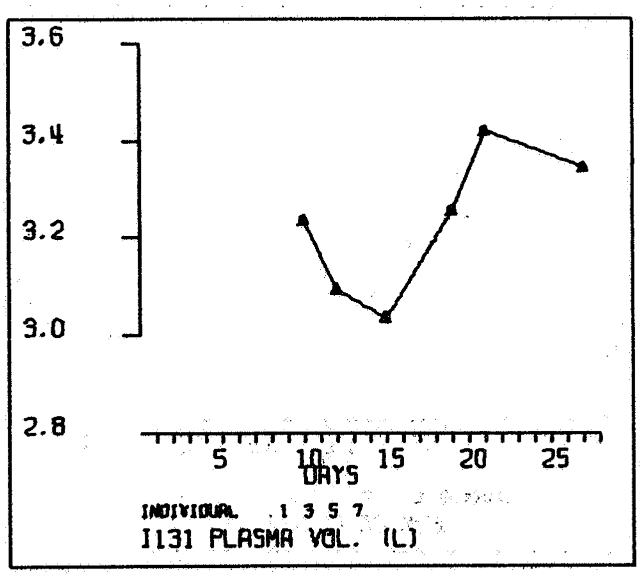
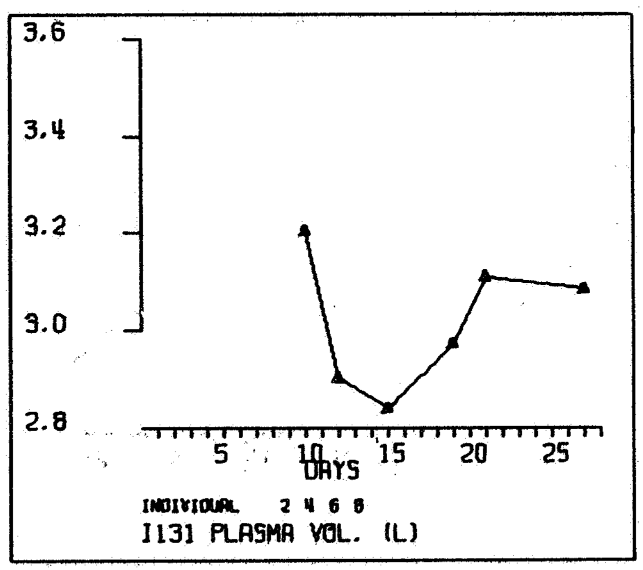
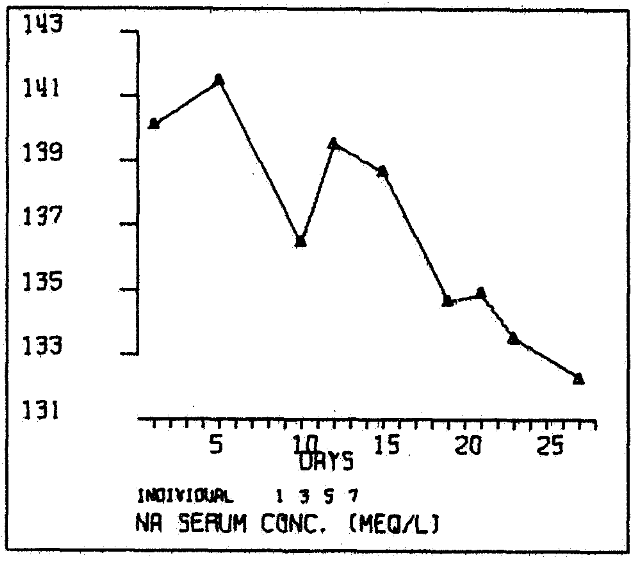
48
47
46
45
44
5 10 15 20 25
DAYS
INDIVIDUAL 2 4 6 8
HEMATOCRIT (PERCENT)


3.6
3.4
3.2
3.0
2.8
5 10 15 20 25
DAYS
INDIVIDUAL 1 3 5 7
I131 PLASMA VOL. (L)


3.6
3.4
3.2
3.0
2.8
5 10 15 20 25
DAYS
INDIVIDUAL 2 4 6 8
I131 PLASMA VOL. (L)


143
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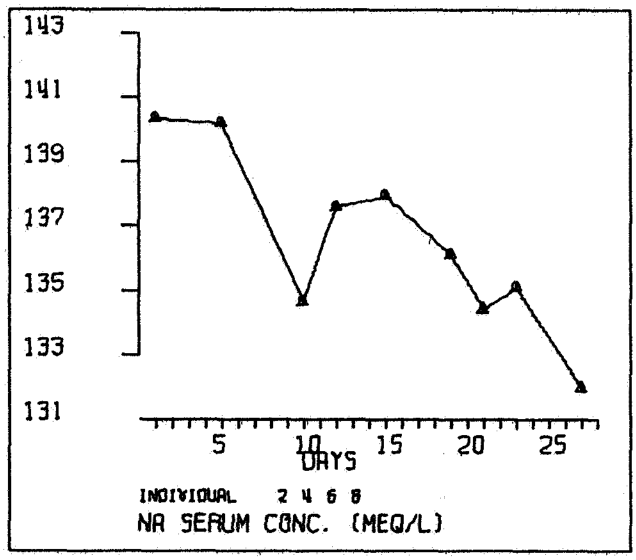
139
137
135
133
131
5 10 15 20 25
DAYS
INDIVIDUAL 1 3 5 7
NA SERUM CONC. (MEQ/L)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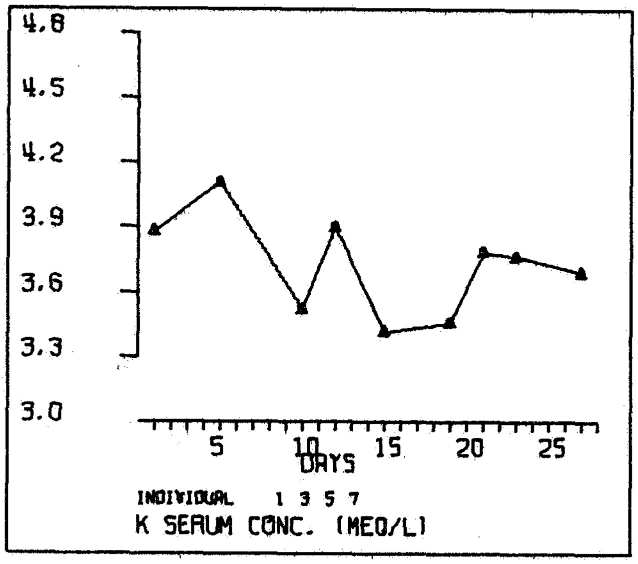
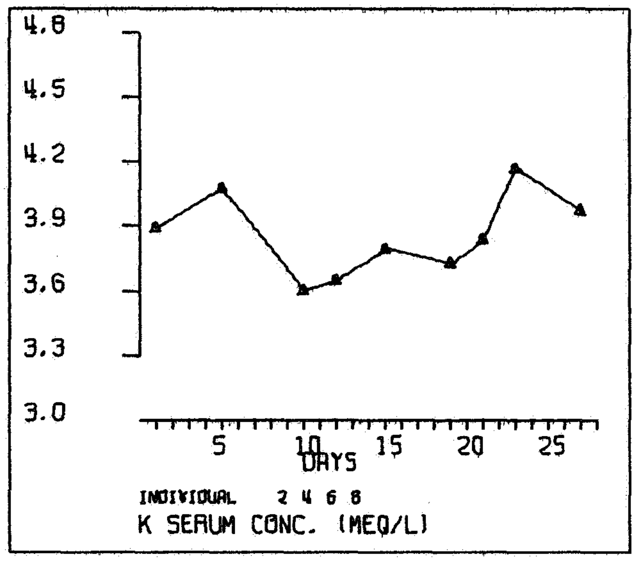
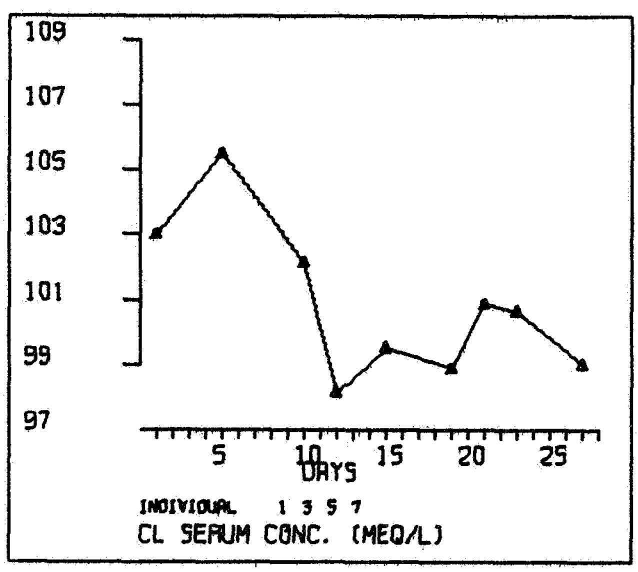
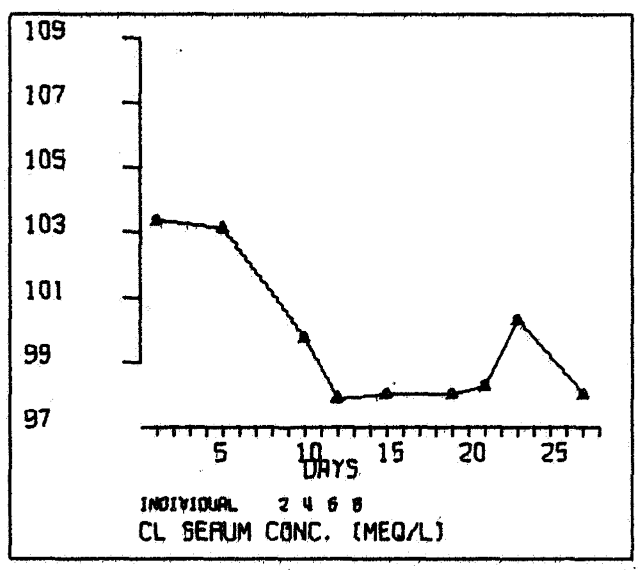
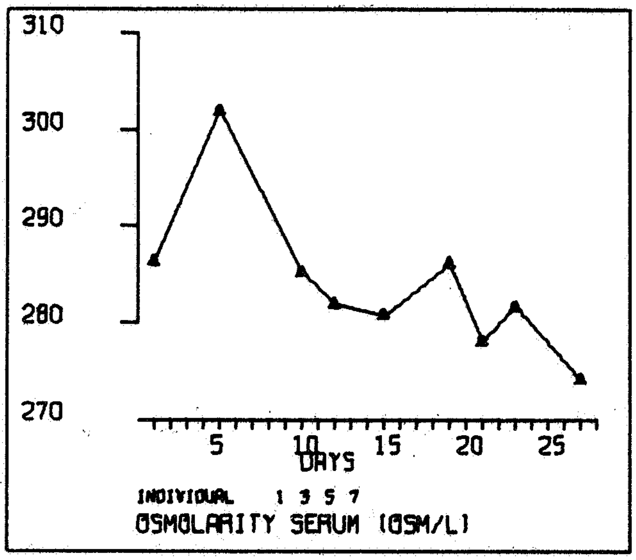
135
133
131
5 10 15 20 25
DAYS
INDIVIDUAL 2 4 6 8
NA SERUM CONC. (MEQ/L)


4.8
4.5
4.2
3.9
3.6
3.3
3.0
5 10 15 20 25
DAYS
INDIVIDUAL 1 3 5 7
K SERUM CONC. (MEQ/L)

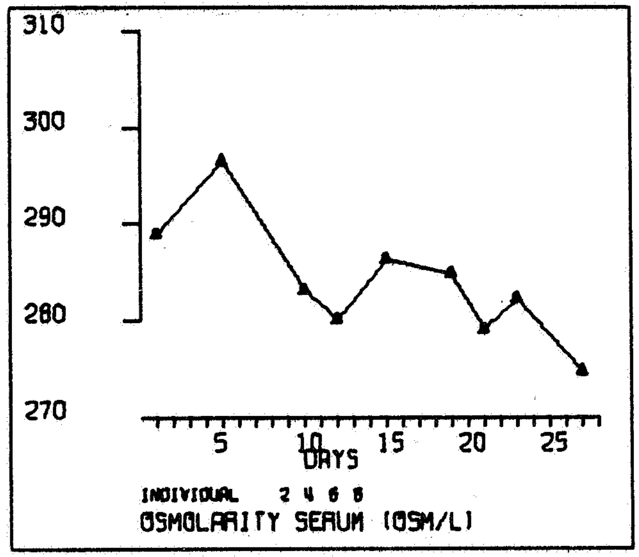

4.8
4.5
4.2
3.9
3.6
3.3
3.0
5 10 15 20 25
DAYS
INDIVIDUAL 2 4 6 8
K SERUM CONC. (MEQ/L)


109
107
105
103
101
99
97
5 10 15 20 25
DAYS
INDIVIDUAL 1 3 5 7
CL SERUM CONC. (MEQ/L)

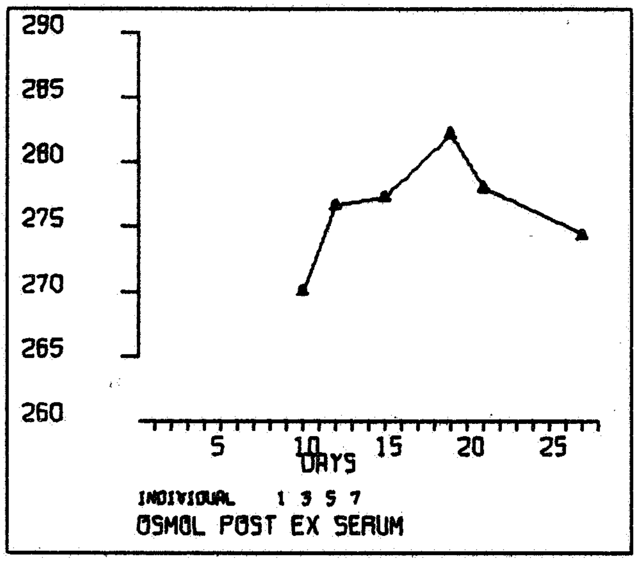

109
107
105
103
101
99
97
5 10 15 20 25
DAYS
INDIVIDUAL 2 4 6 8
CL SERUM CONC. (MEQ/L)



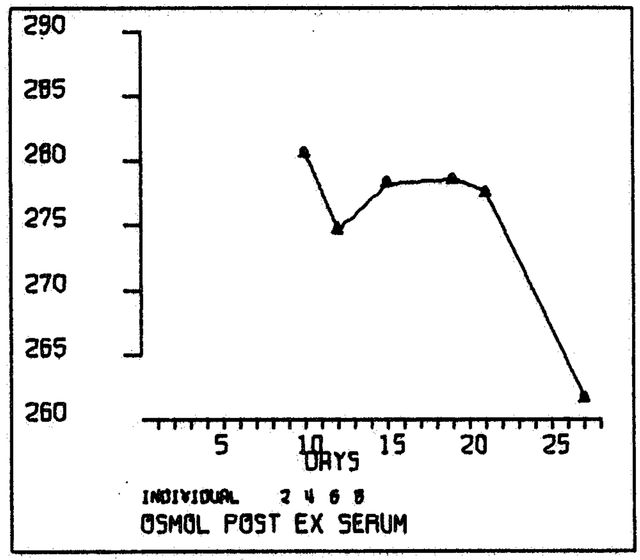
310
300
290
280
270
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
OSMOLARITY SERUM (OSM/L)



310
300
290
280
270
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
OSMOLARITY SERUM (OSM/L)



290
285
280
275
270
265
260
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
OSMOL POST EX SERUM



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DAYS
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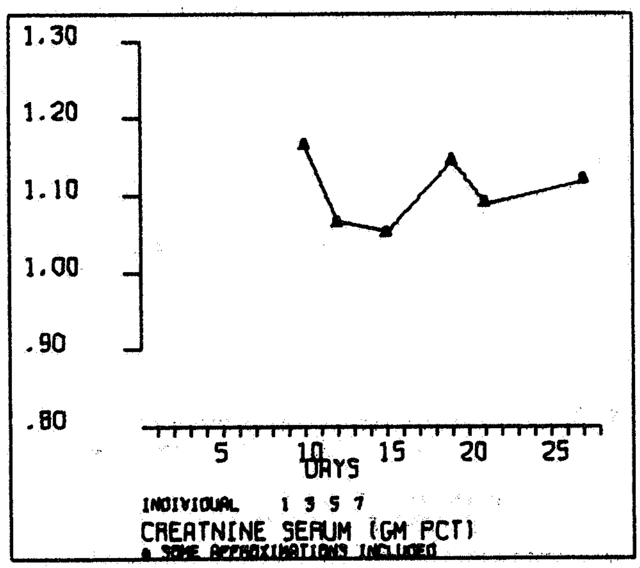

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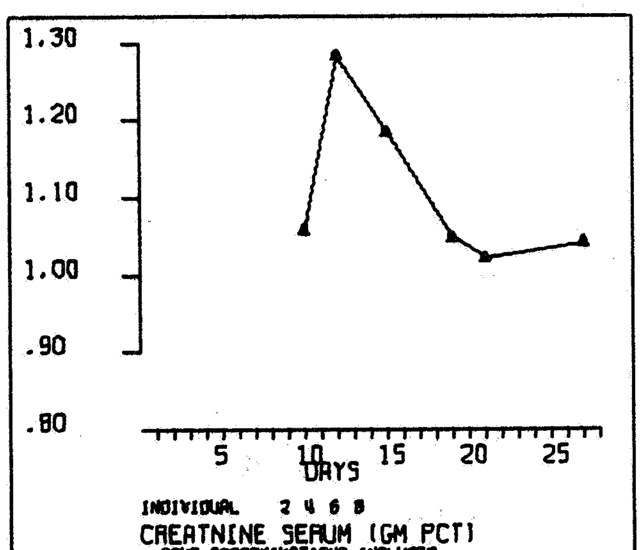

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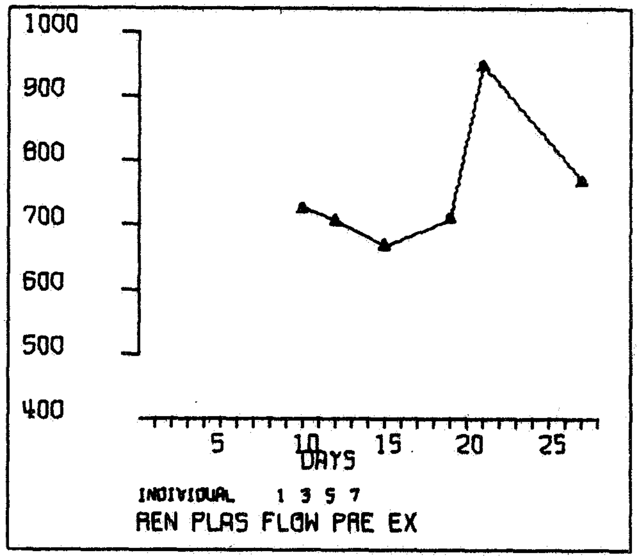
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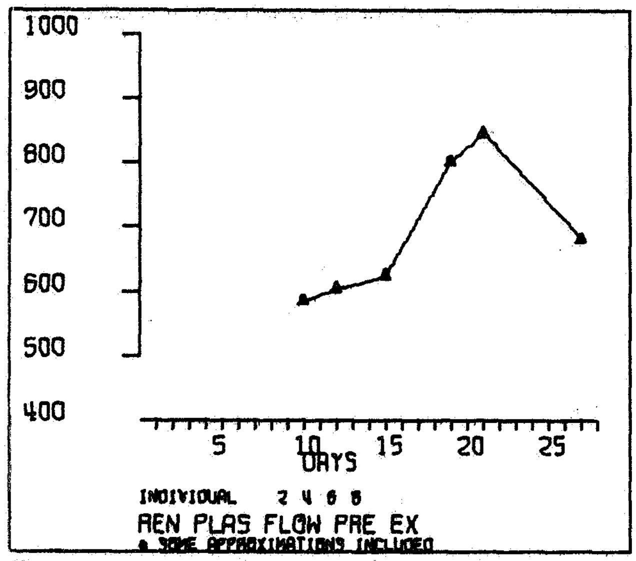
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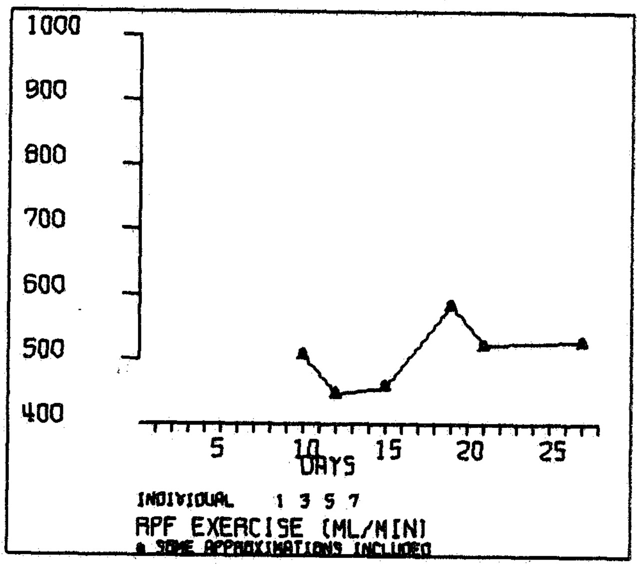
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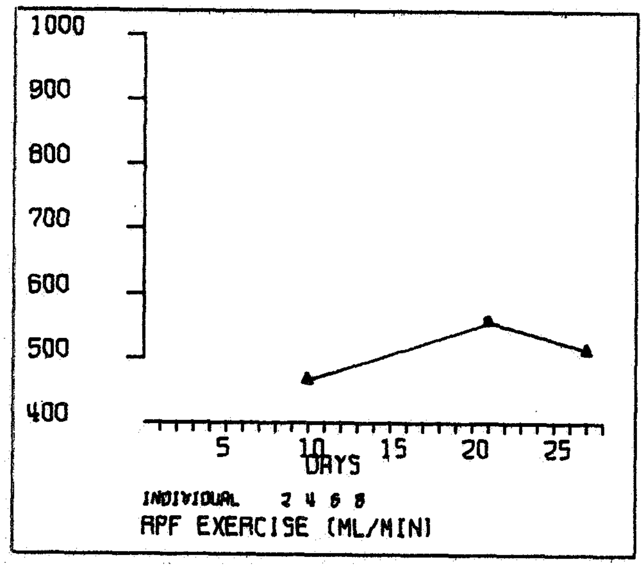
RPF EXERCISE (ML/MIN)
* SOME APPROXIMATIONS INCLUDED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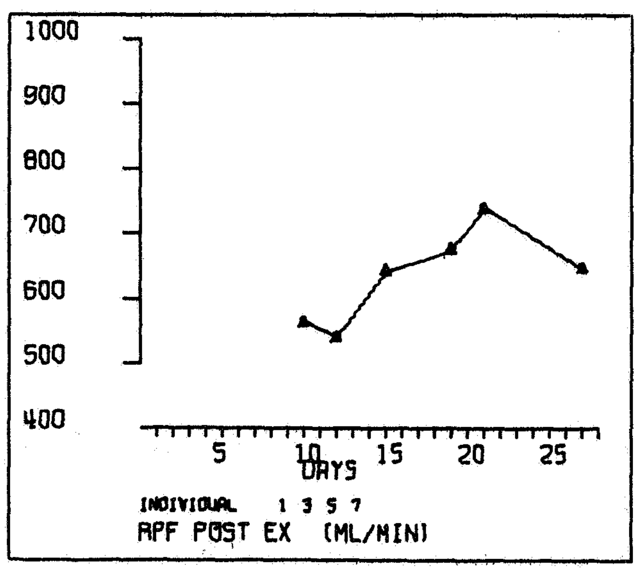
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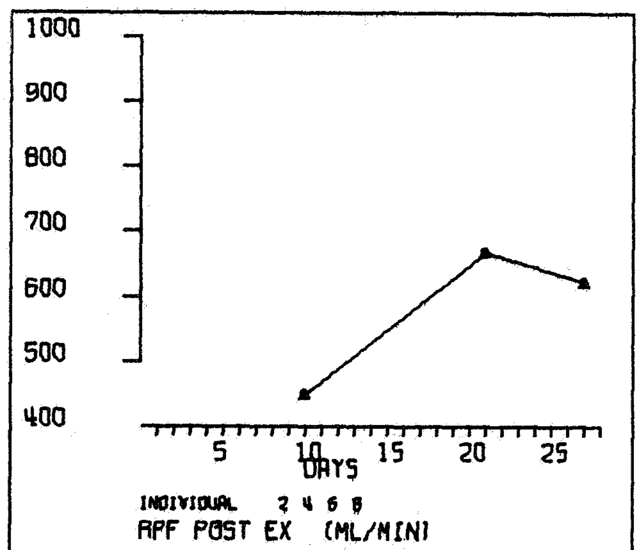
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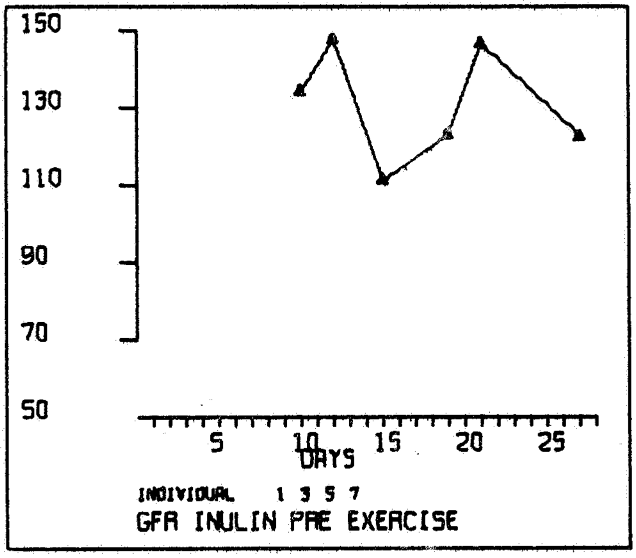

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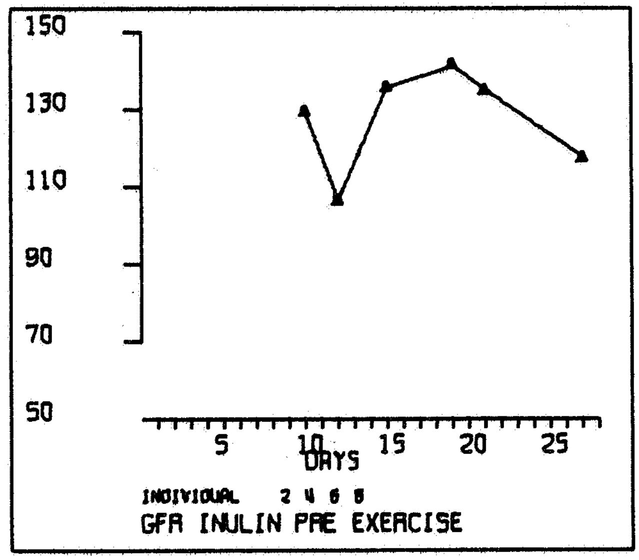
GFR INULIN PRE EXERCISE



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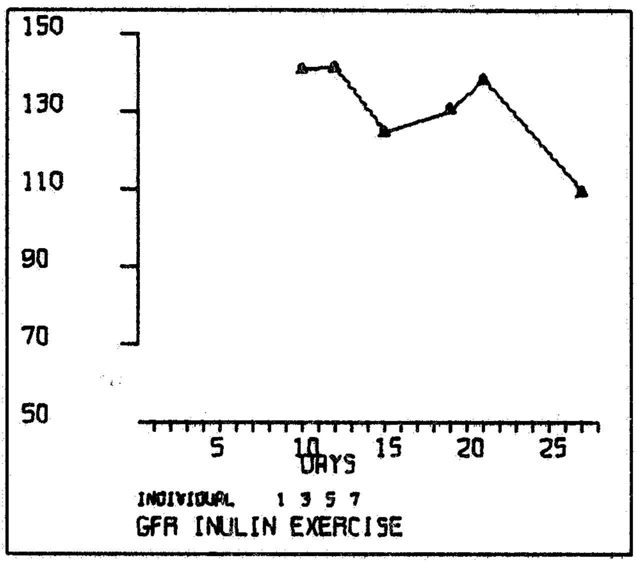

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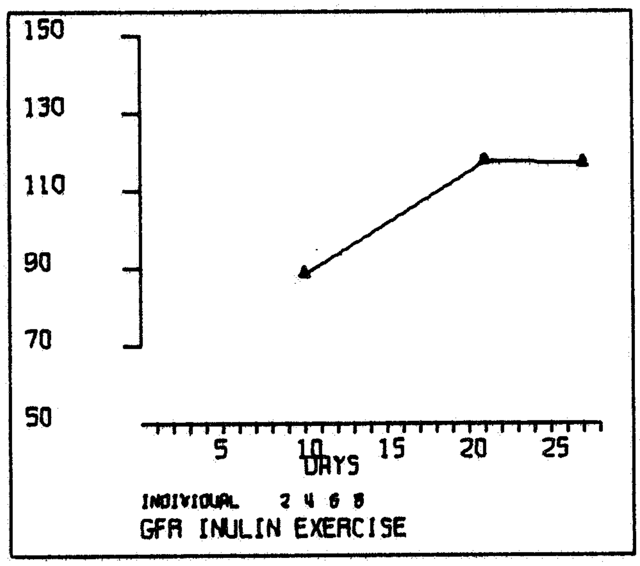
GFR INULIN EXERCISE



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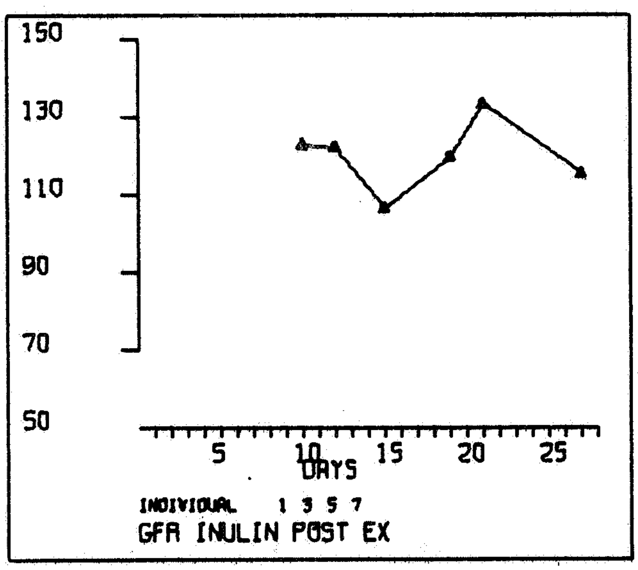
GFR INULIN EXERCISE



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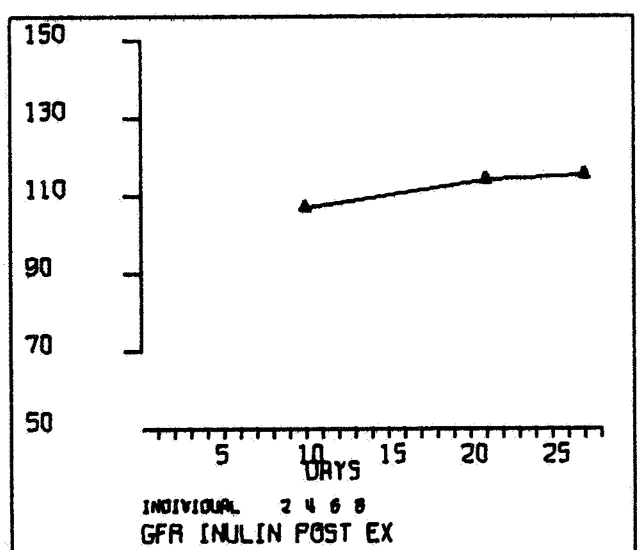
GFR INULIN POST EX



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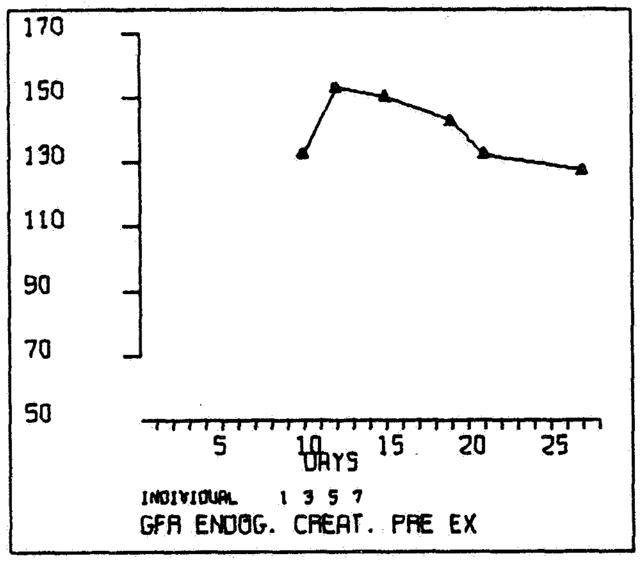
GFR INULIN POST EX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DAYS
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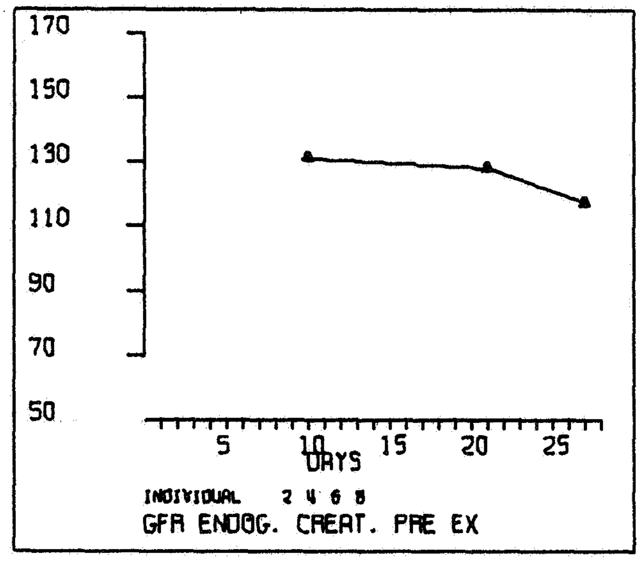
GFR ENDOG. CREAT. PRE EX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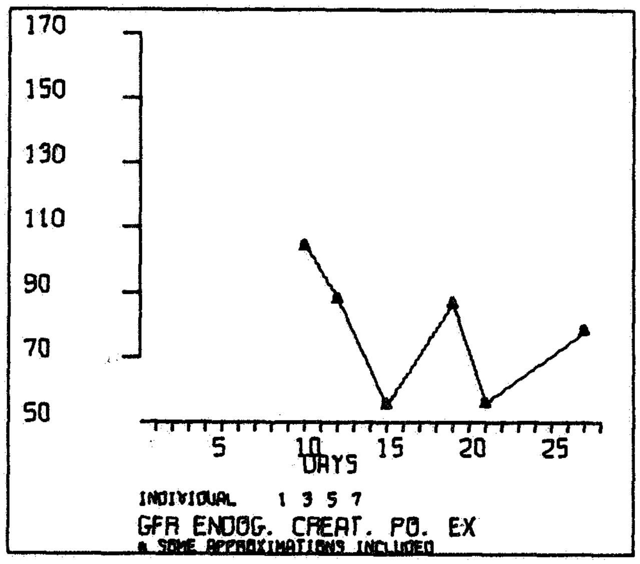
GFR ENDOG. CREAT. PRE EX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DAYS
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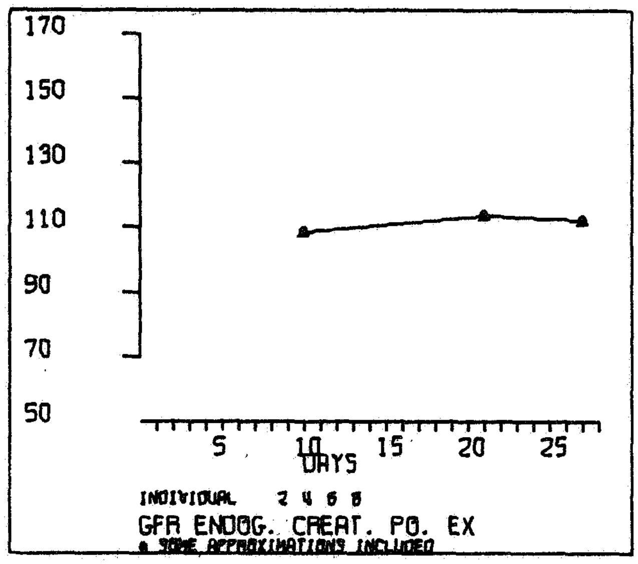
GFR ENDOG. CREAT. PO. EX
* SOME APPROXIMATIONS INCLUDED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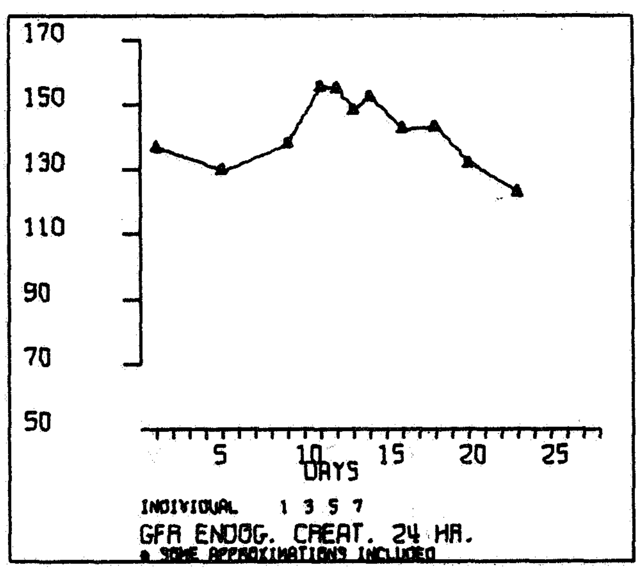
GFR ENDOG. CREAT. PO. EX
* SOME APPROXIMATIONS INCLUDED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DAYS
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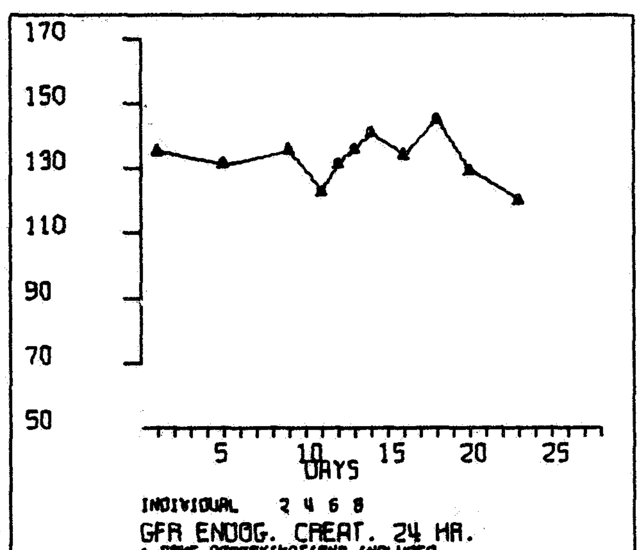
GFR ENDOG. CREAT. 24 HR.
* SOME APPROXIMATIONS INCLUDED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DAYS
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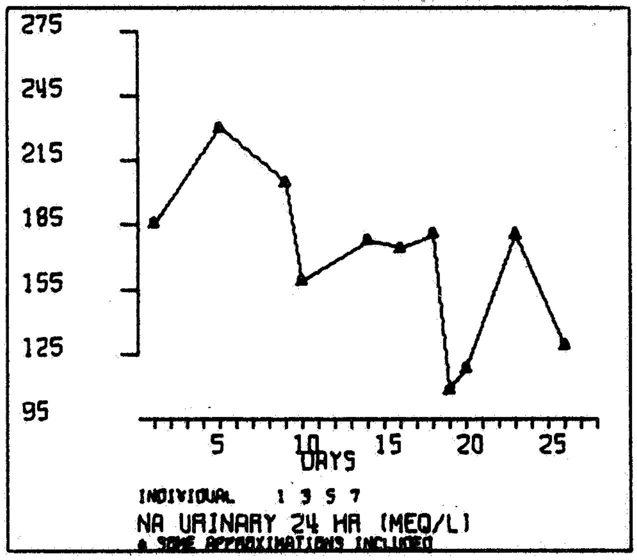
GFR ENDOG. CREAT. 24 HR.
* SOME APPROXIMATIONS INCLUDED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DAYS
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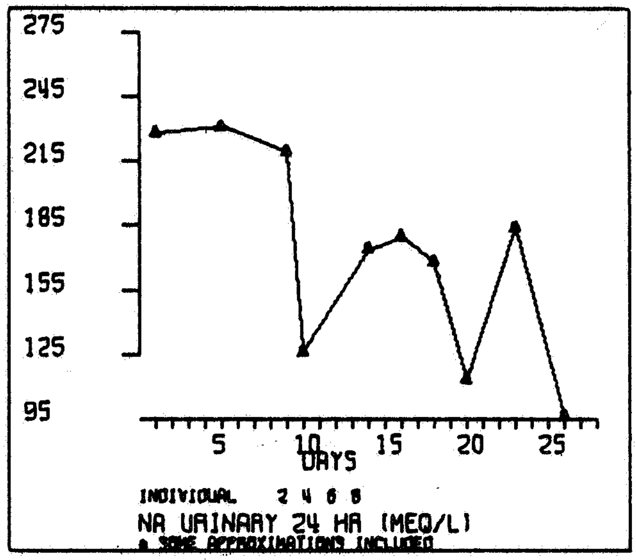
NA URINARY 24 HR (MEQ/L)
* SOME APPROXIMATIONS INCLUDED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DAYS
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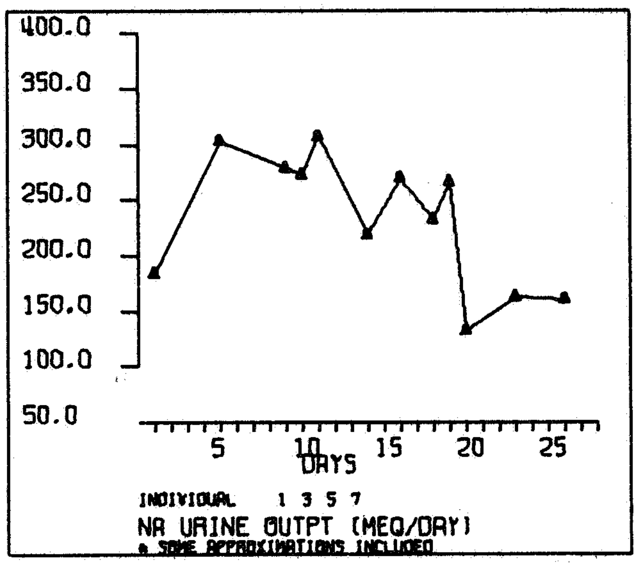
NA URINARY 24 HR (MEQ/L)
* SOME APPROXIMATIONS INCLUDED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DAYS
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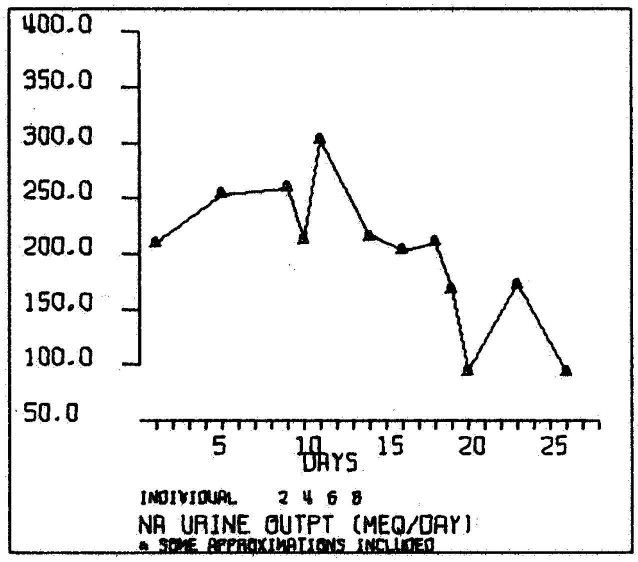
NA URINE OUTPT (MEQ/DAY)
* SOME APPROXIMATIONS INCLUDED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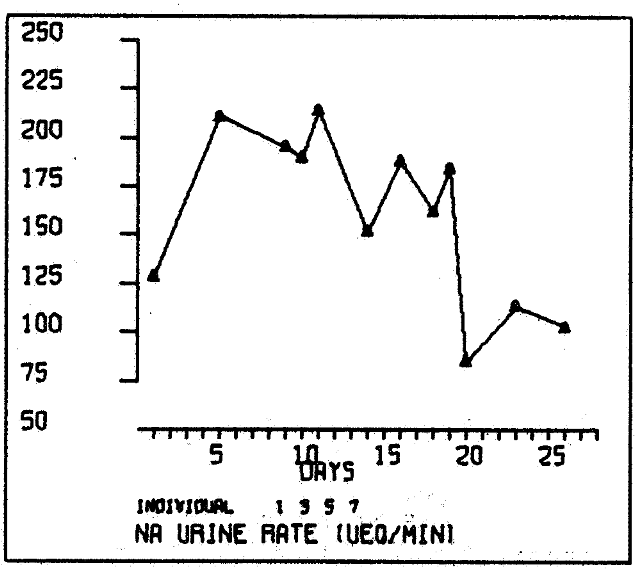
* SOME APPROXIMATIONS INCLUDED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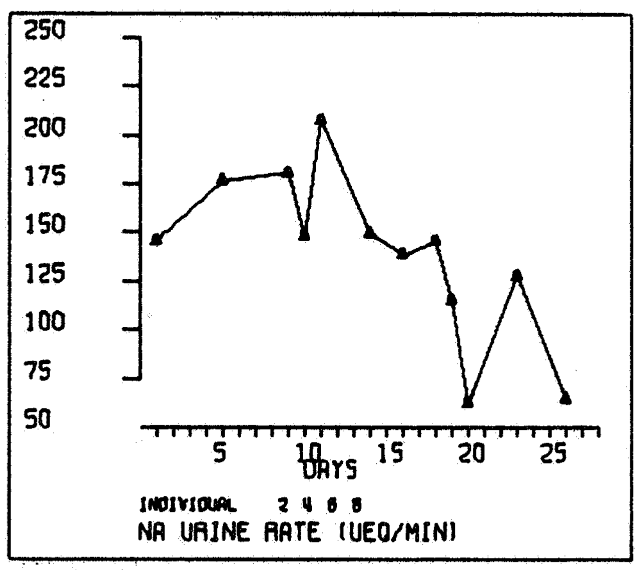
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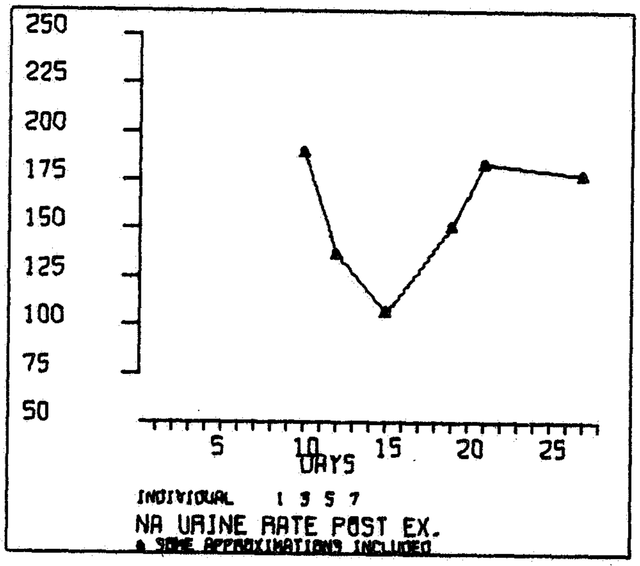
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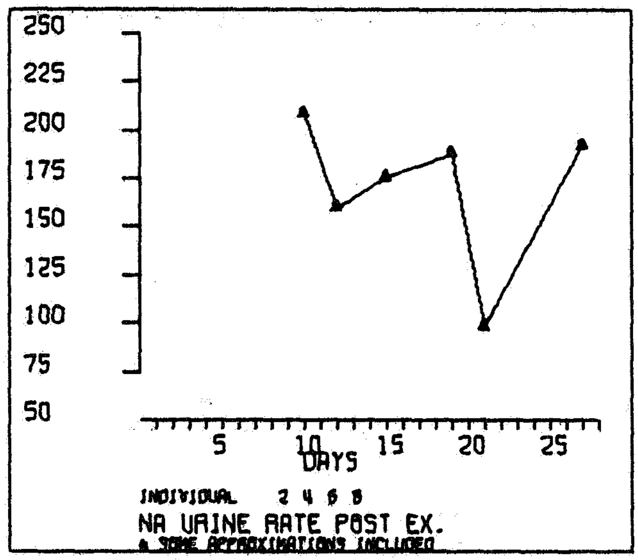
NA URINE RATE POST EX.
* SOME APPROXIMATIONS INCLUDED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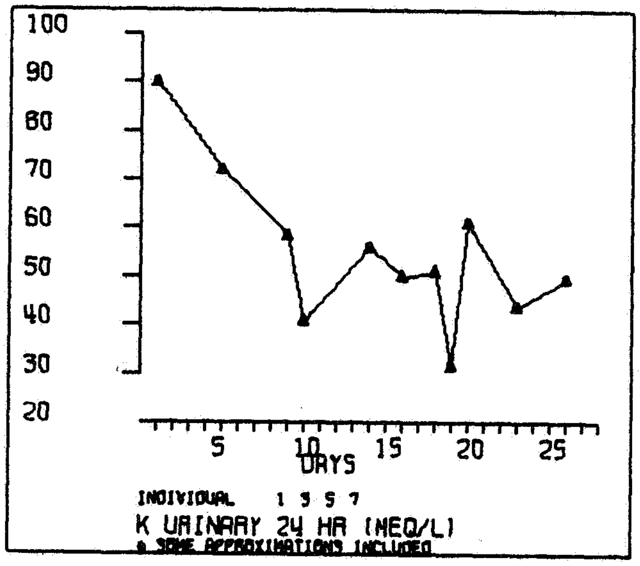
* SOME APPROXIMATIONS INCLUDED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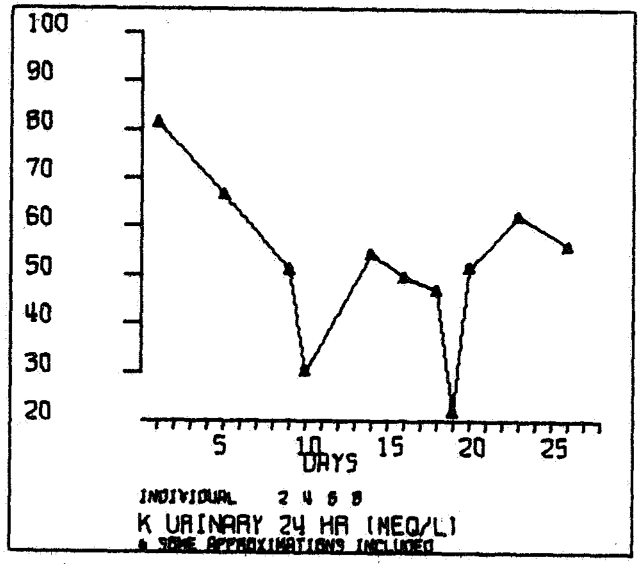
K URINARY 24 HR (MEQ/L)
* SOME APPROXIMATIONS INCLUDED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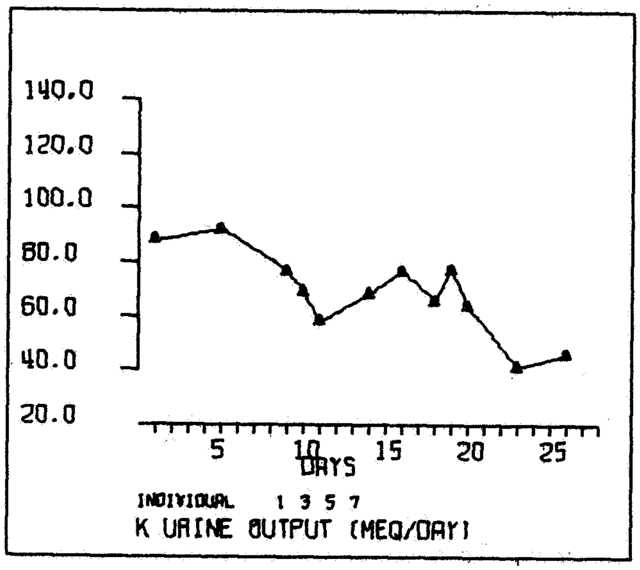
* SOME APPROXIMATIONS INCLUDED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DAYS
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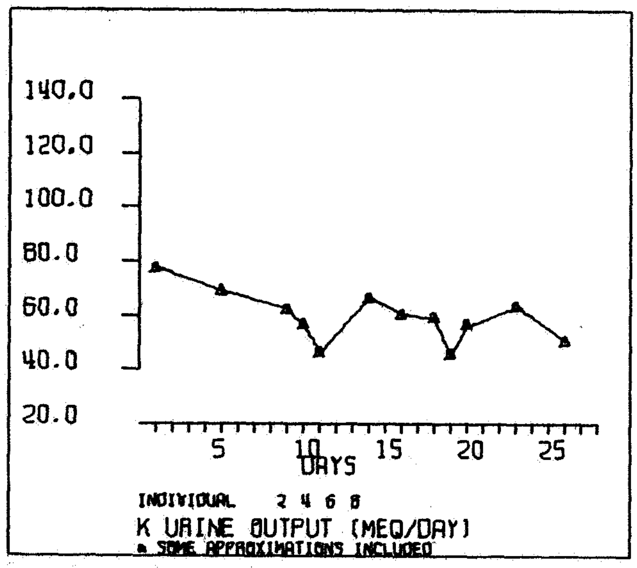
K URINE OUTPUT (MEQ/DAY)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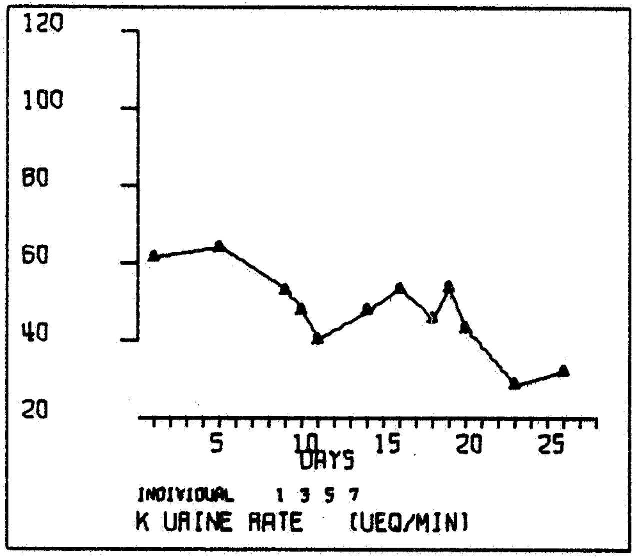
K URINE OUTPUT (MEQ/DAY)
* SOME APPROXIMATIONS INCLUDED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DAYS
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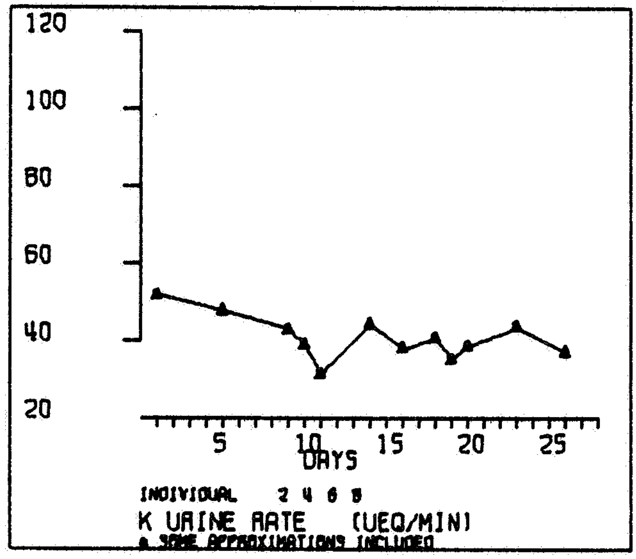
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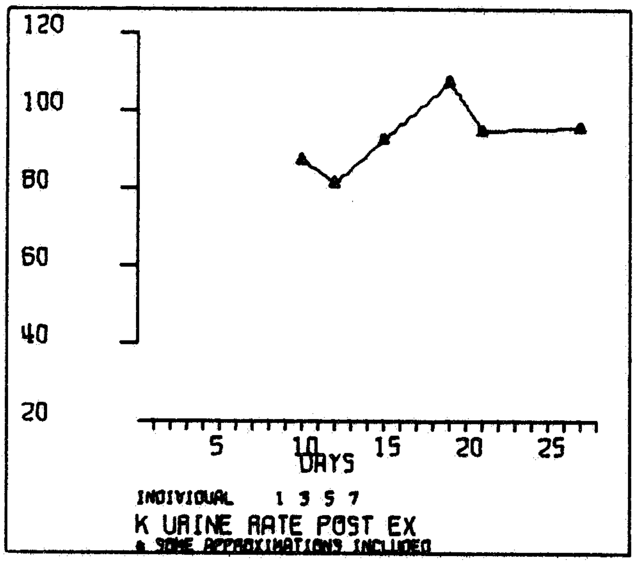
K URINE RATE (UEQ/MIN)
* SOME APPROXIMATIONS INCLUDED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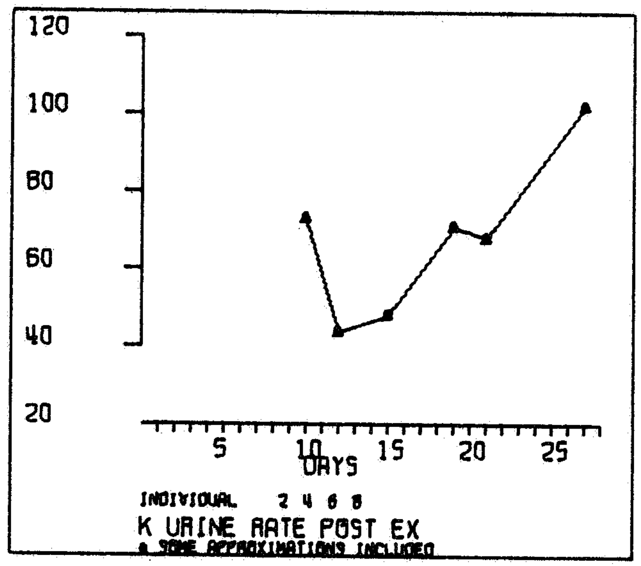
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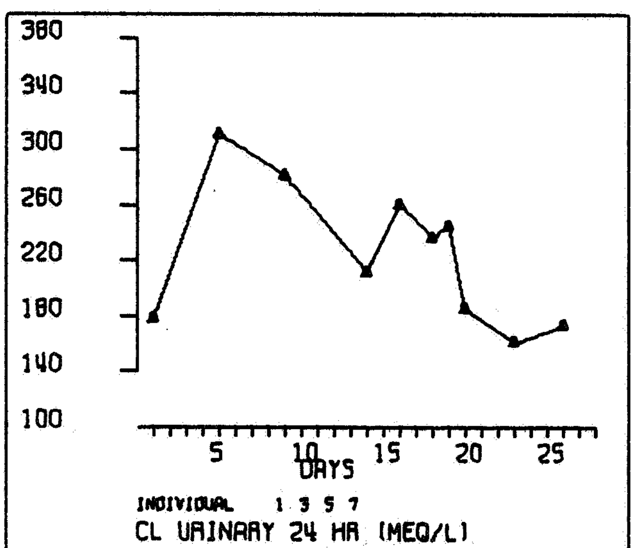
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DAYS
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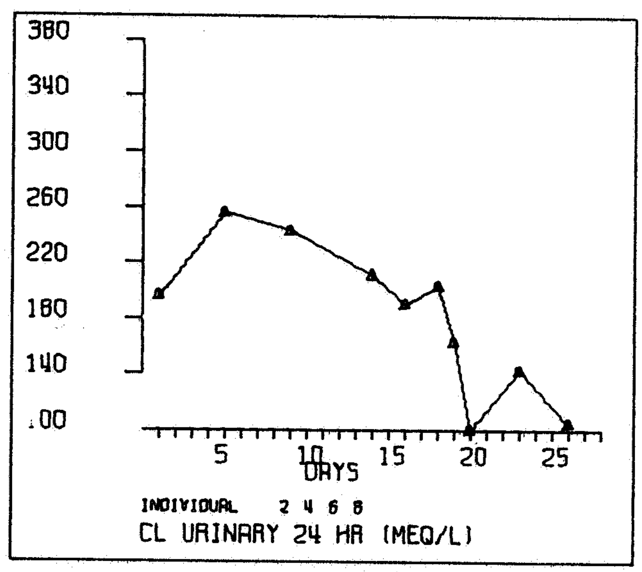
CL URINARY 24 HR (MEQ/L)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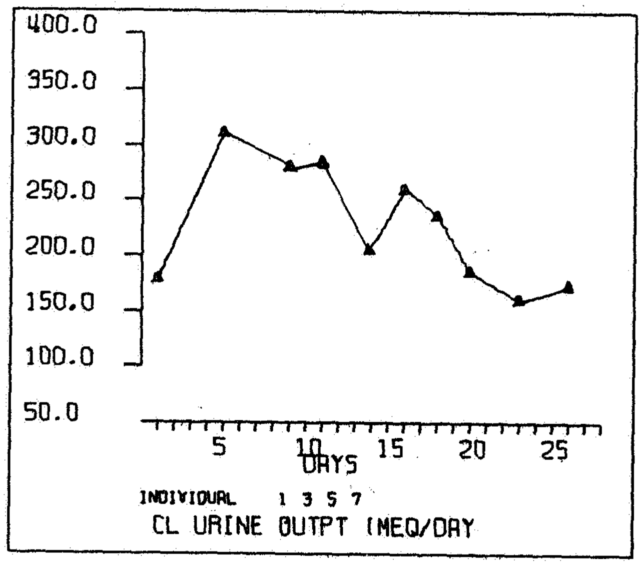
CL URINARY 24 HR (MEQ/L)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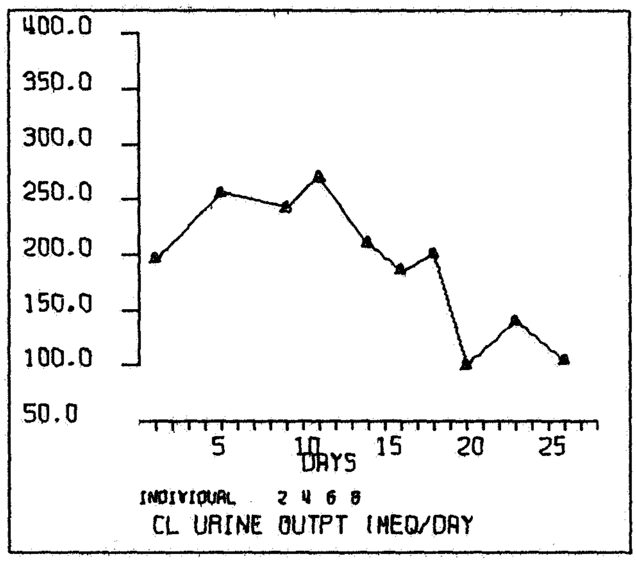
DAYS
INDIVIDUAL 1 3 5 7
CL URINE OUTPT (MEQ/DAY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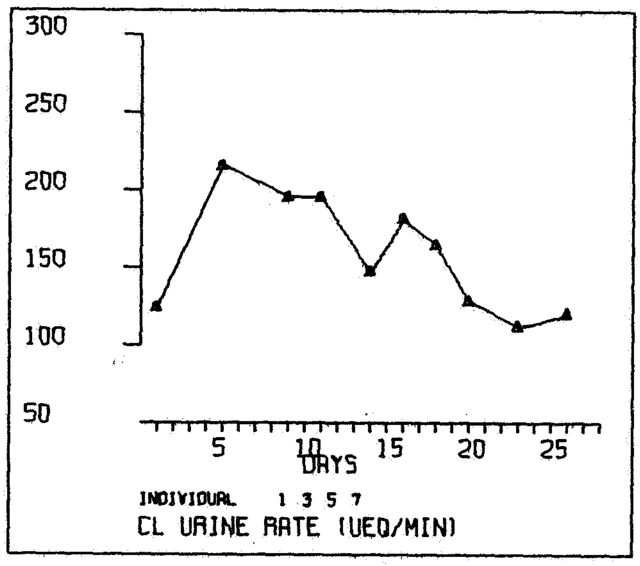
CL URINE OUTPT (MEQ/DAY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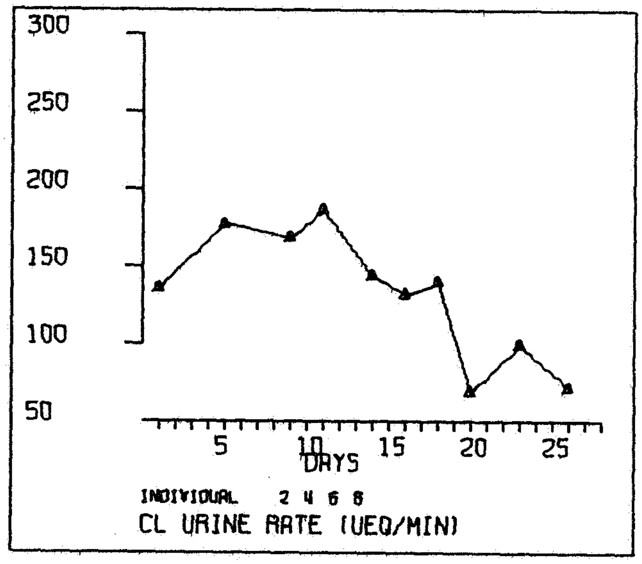
DAYS
INDIVIDUAL 1 3 5 7
CL URINE RATE (UEQ/MIN)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DAYS
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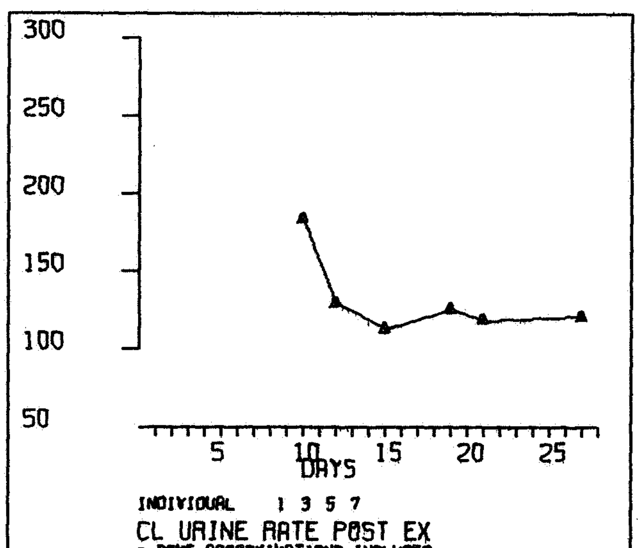
CL URINE RATE (UEQ/MIN)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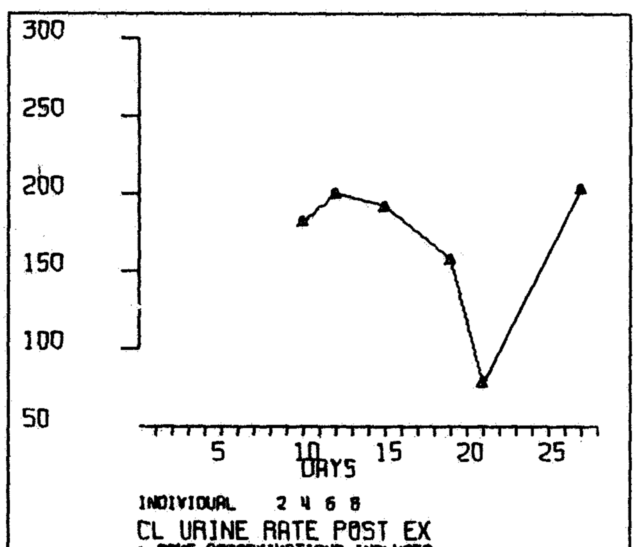
DAYS
INDIVIDUAL 1 3 5 7
CL URINE RATE POST EX
* SOME APPROXIMATIONS INCLUDED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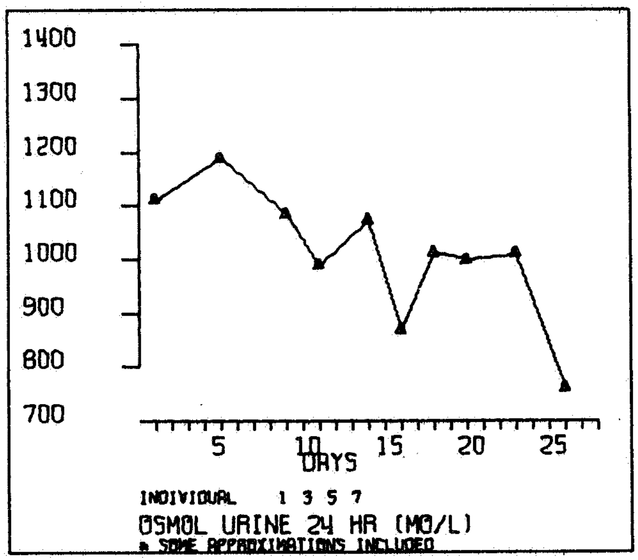
CL URINE RATE POST EX
* SOME APPROXIMATIONS INCLUDED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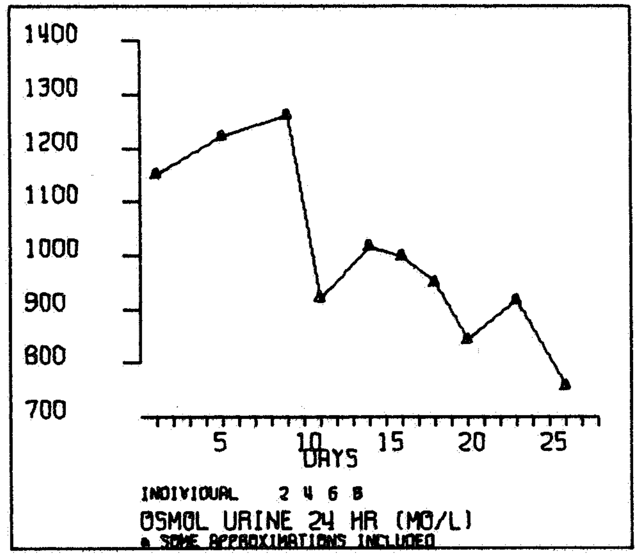
DAYS
INDIVIDUAL 1 3 5 7
OSMOL URINE 24 HR (MO/L)
* SOME APPROXIMATIONS INCLUDED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DAYS
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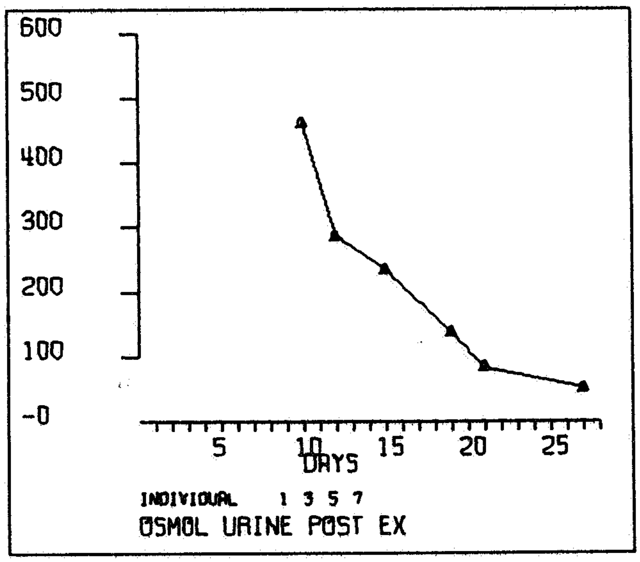
OSMOL URINE 24 HR (MO/L)
* SOME APPROXIMATIONS INCLUDED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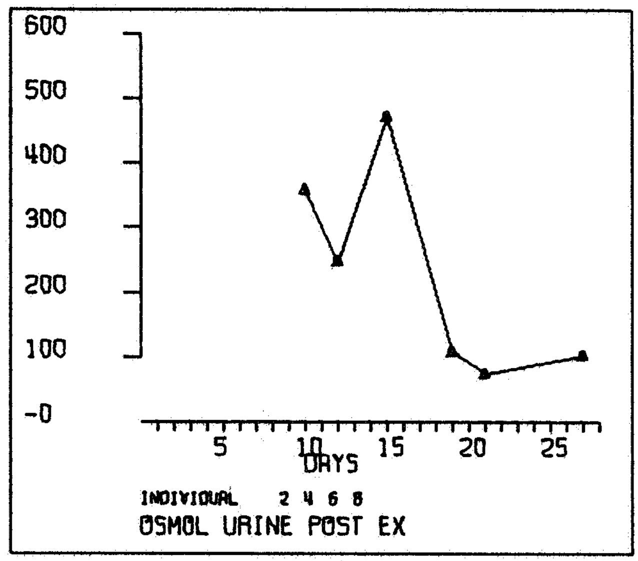
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
OSMOL URINE POST EX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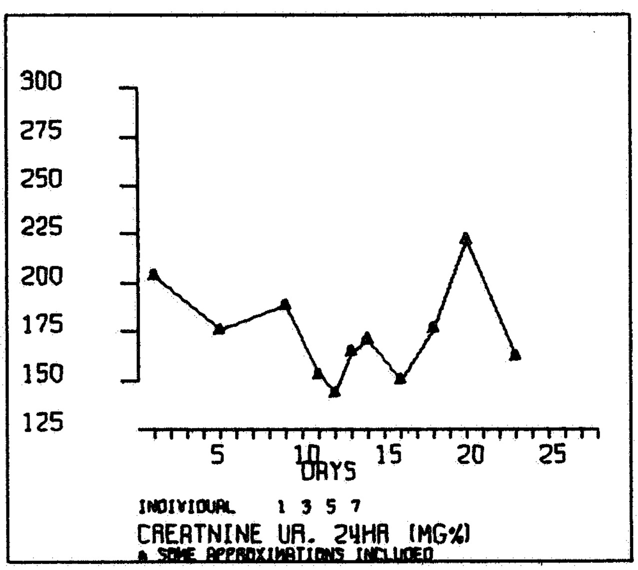
DAYS
INDIVIDUAL 2 4 6 8
OSMOL URINE POST EX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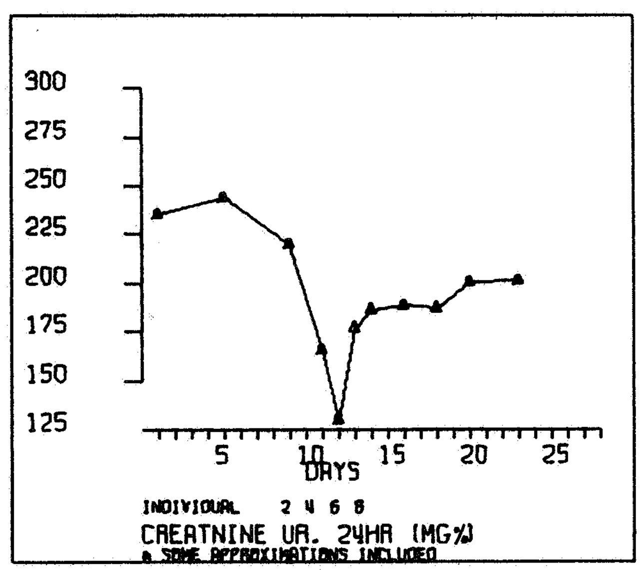
DAYS
INDIVIDUAL 1 3 5 7
CREATNINE UR. 24HR (MG%)
* SOME APPROXIMATIONS INCLUDED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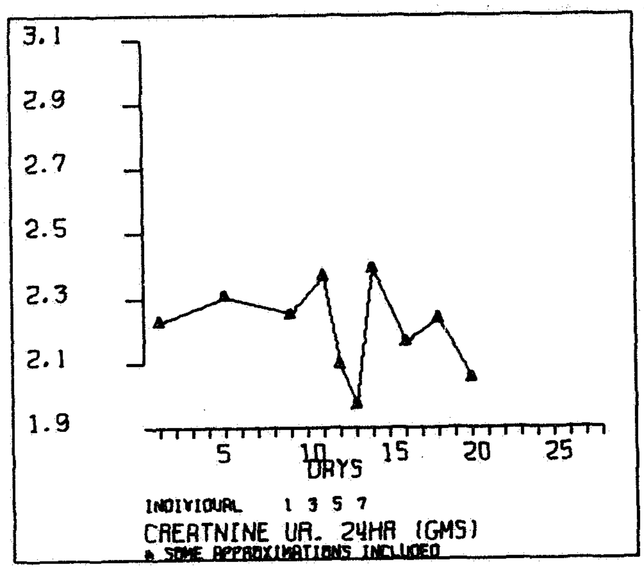
DAYS
INDIVIDUAL 2 4 6 8
CREATNINE UR. 24HR (MG%)
* SOME APPROXIMATIONS INCLUDED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1.9
5
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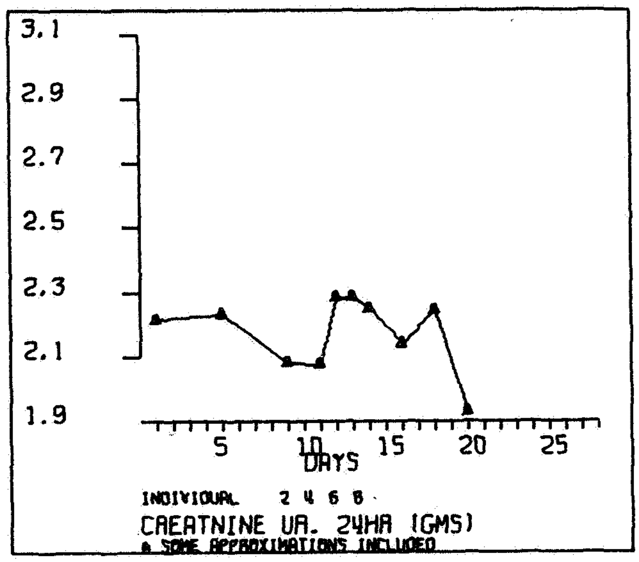
25
DAYS
INDIVIDUAL 1 3 5 7
CREATNINE UR. 24HR (GMS)
* SOME APPROXIMATIONS INCLUDED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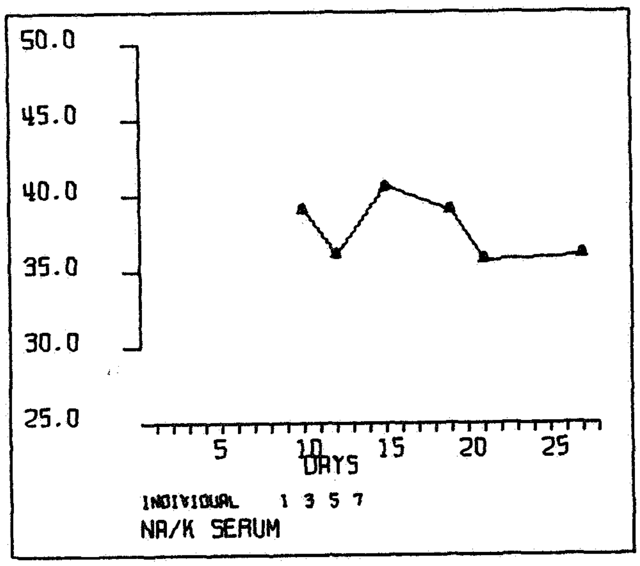
DAYS
INDIVIDUAL 2 4 6 8
CREATNINE UR. 24HR (GMS)
* SOME APPROXIMATIONS INCLUDED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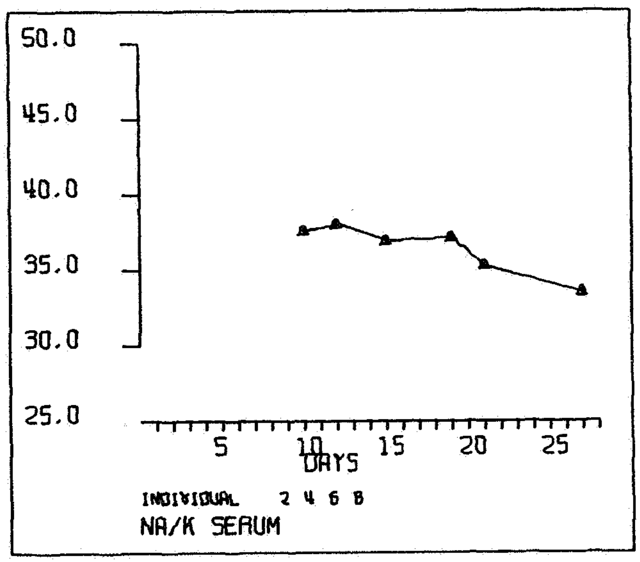
DAYS
INDIVIDUAL 1 3 5 7
NA/K SERUM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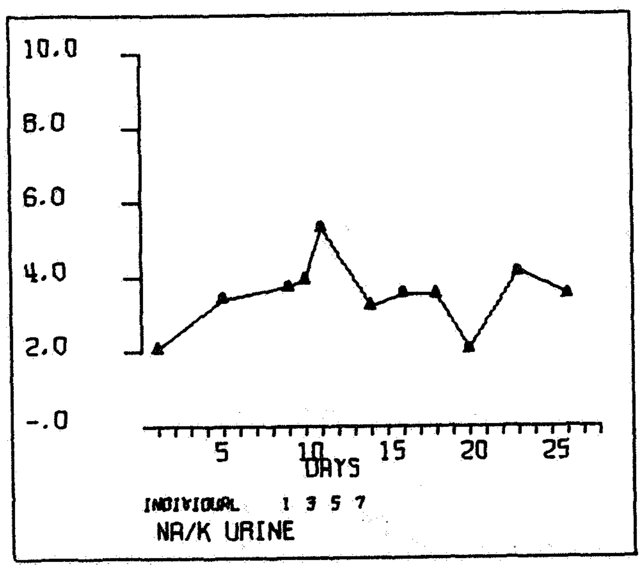
DAYS
INDIVIDUAL 2 4 6 8
NA/K SERUM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15
20
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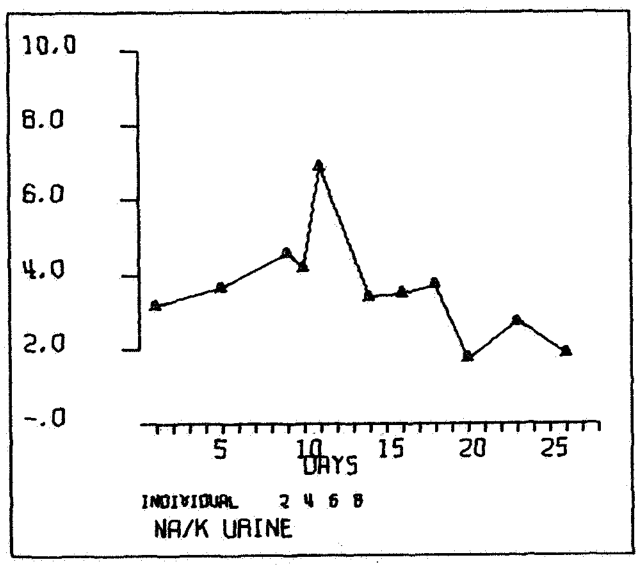
DAYS
INDIVIDUAL 1 3 5 7
NA/K URINE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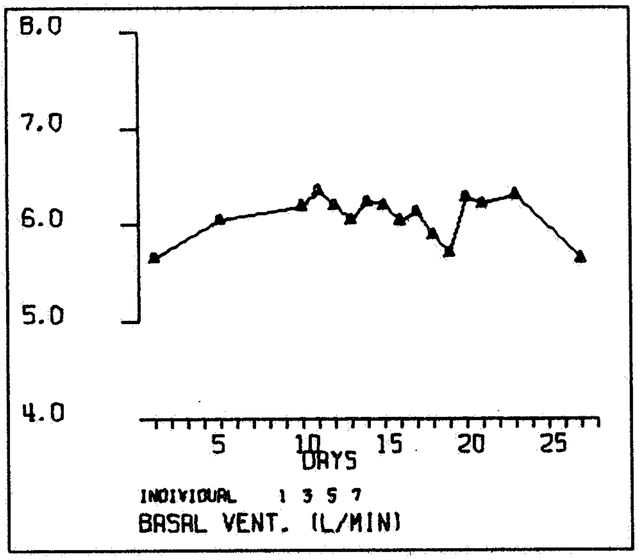
DAYS
INDIVIDUAL 2 4 6 8
NA/K URINE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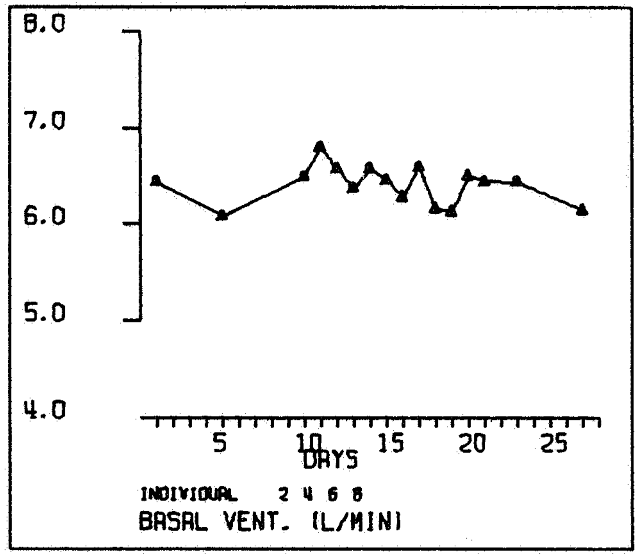
DAYS
INDIVIDUAL 1 3 5 7
BASAL VENT. (L/MIN)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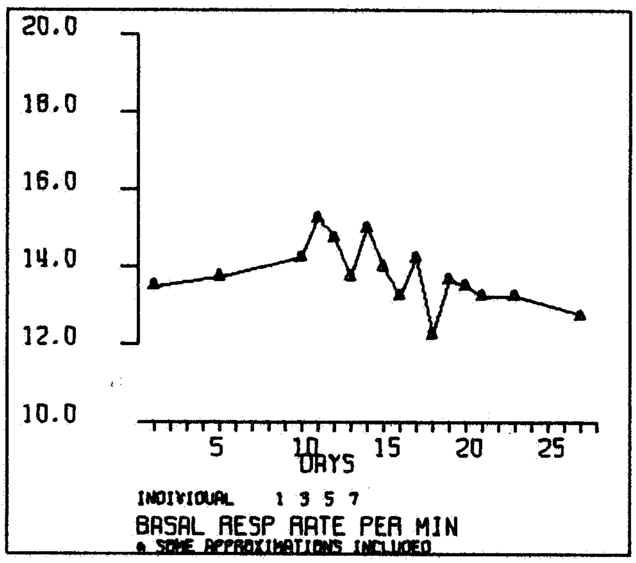
DAYS
INDIVIDUAL 2 4 6 8
BASAL VENT. (L/MIN)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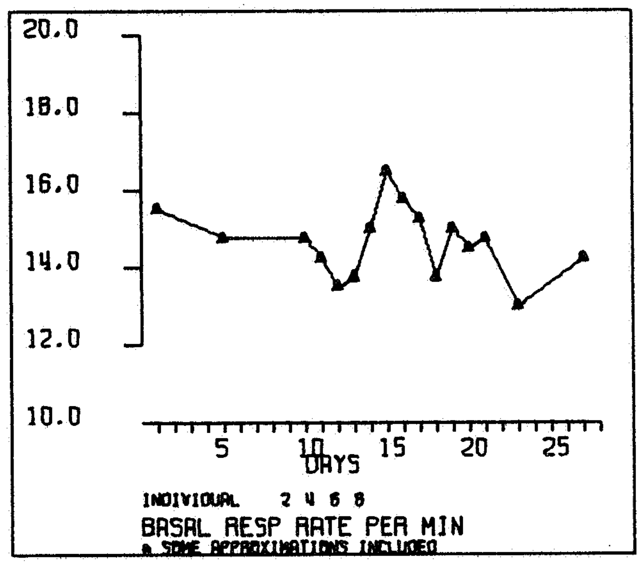
DAYS
INDIVIDUAL 1 3 5 7
BASAL RESP RATE PER MIN
* SOME APPROXIMATIONS INCLUDED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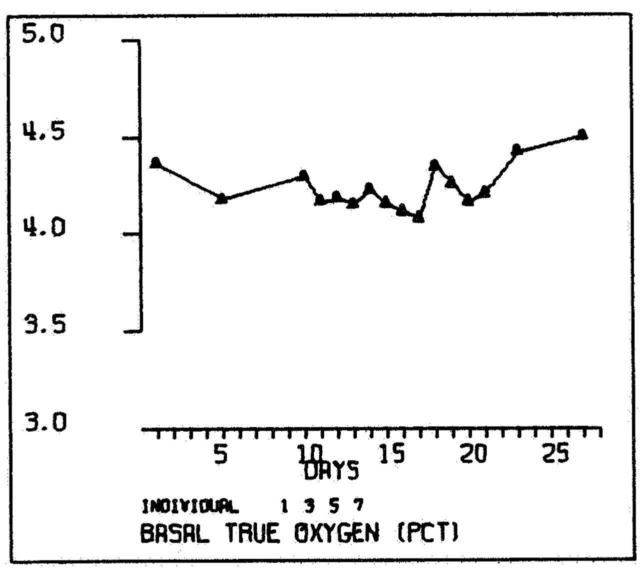
5 10 15 20 25
DAYS
INDIVIDUAL 2 4 6 8
BASAL RESP RATE PER MIN
* SOME APPROXIMATIONS INCLUDED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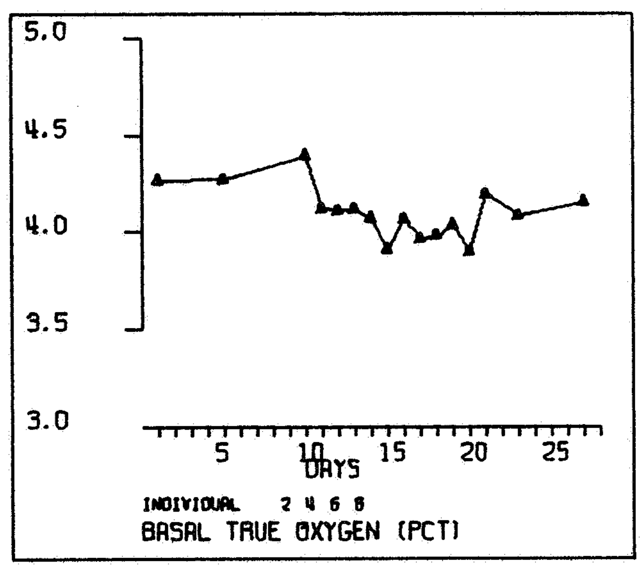
4.0
3.5
3.0
5 10 15 20 25
DAYS
INDIVIDUAL 1 3 5 7
BASAL TRUE OXYGEN (PCT)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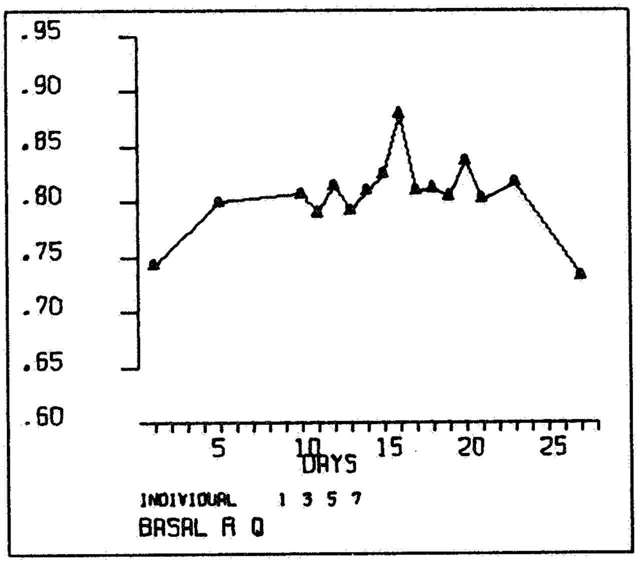
5 10 15 20 25
DAYS
INDIVIDUAL 2 4 6 8
BASAL TRUE OXYGEN (PCT)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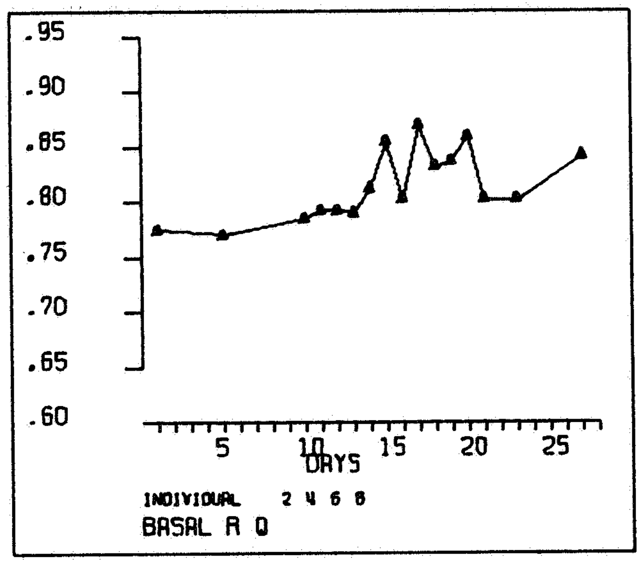
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
BASAL R Q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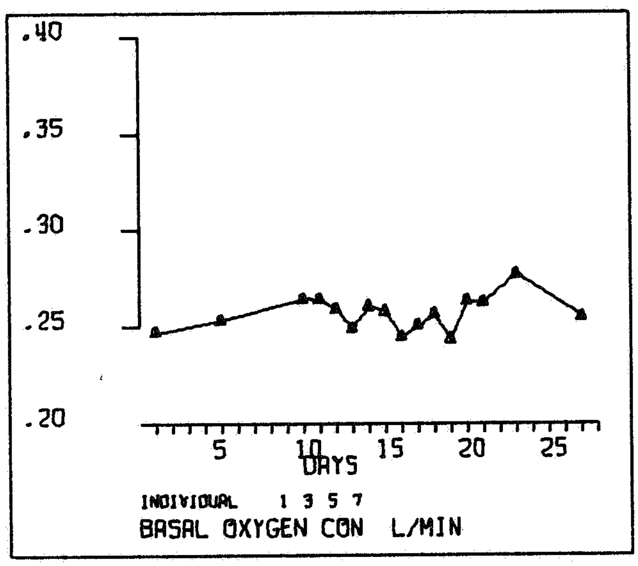
DAYS
INDIVIDUAL 2 4 6 8
BASAL R Q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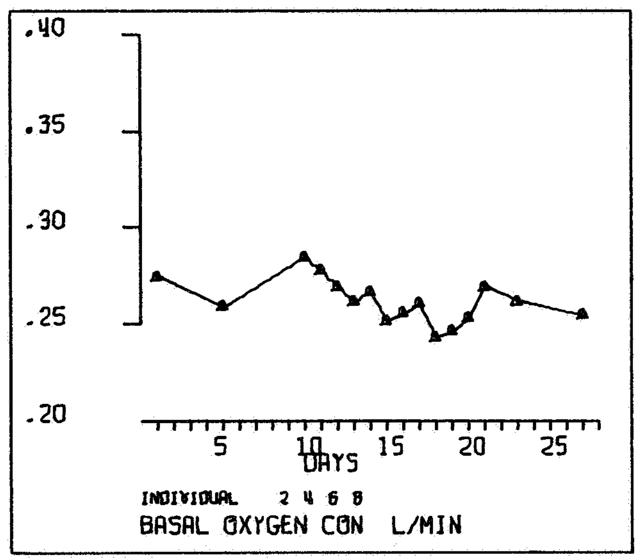
20
25
DAYS
INDIVIDUAL 1 3 5 7
BASAL OXYGEN CON L/MIN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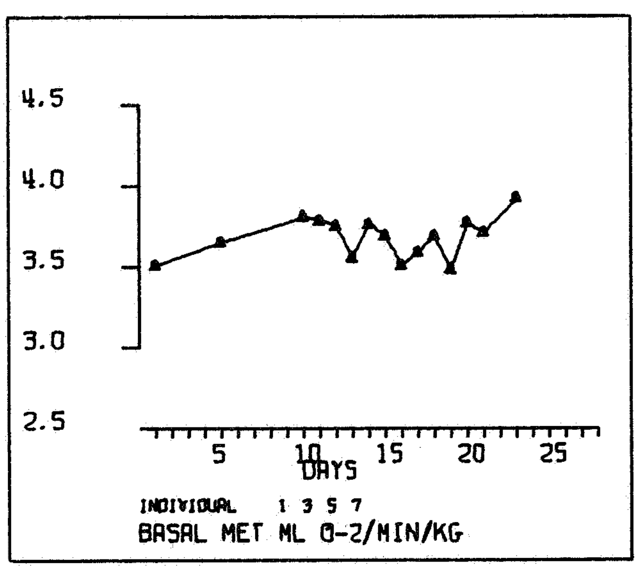
DAYS
INDIVIDUAL 2 4 6 8
BASAL OXYGEN CON L/MIN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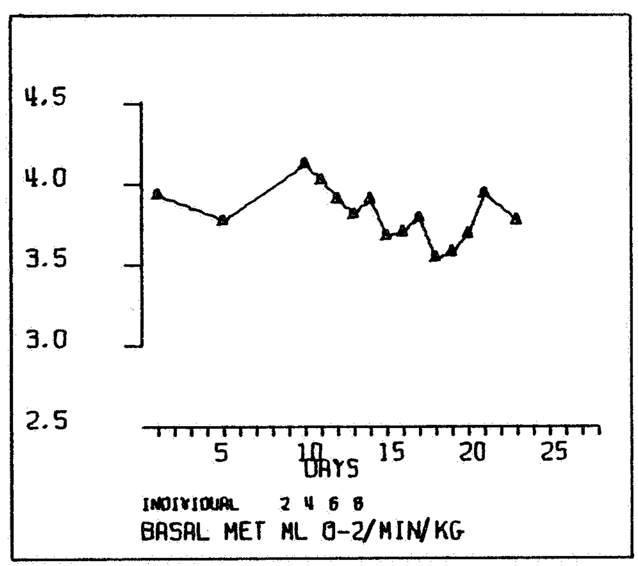
3.5
3.0
2.5
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
BASAL MET ML O-2/MIN/KG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3.0
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5
10
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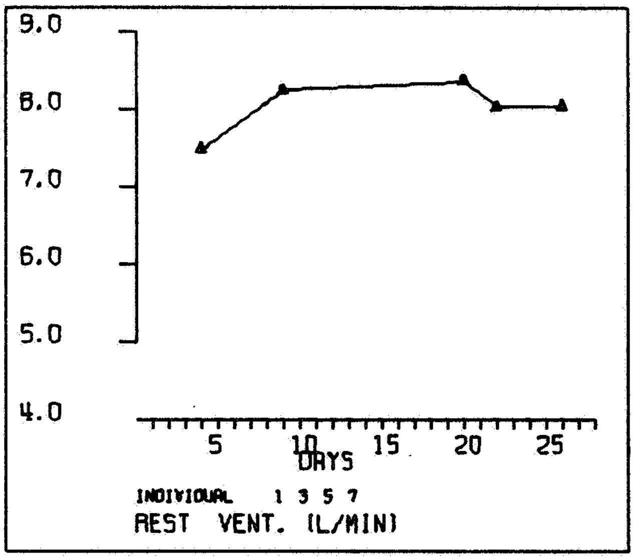
25
DAYS
INDIVIDUAL 2 4 6 8
BASAL MET ML O-2/MIN/KG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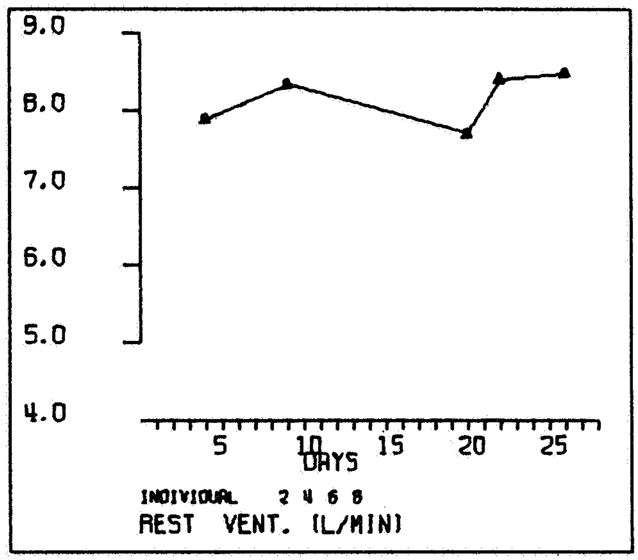
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
REST VENT. (L/MIN)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15
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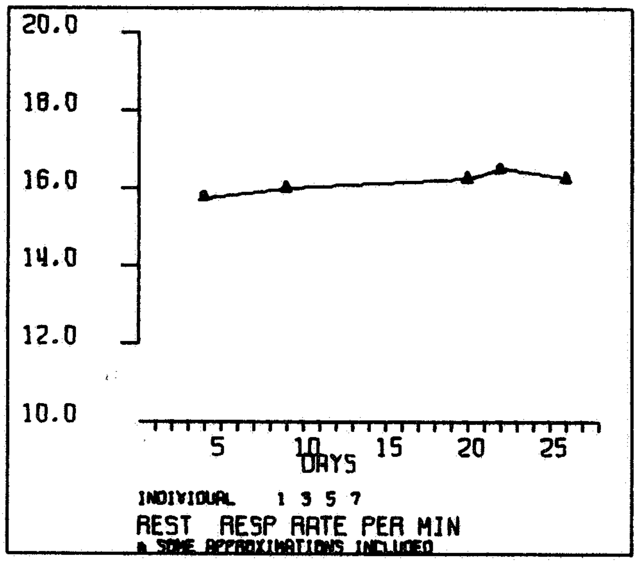
DAYS
INDIVIDUAL 2 4 6 8
REST VENT. (L/MIN)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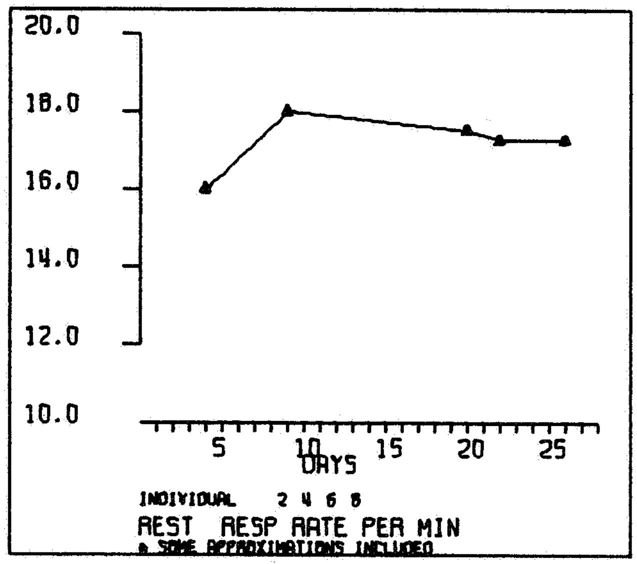
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
REST RESP RATE PER MIN
* SOME APPROXIMATIONS INCLUDED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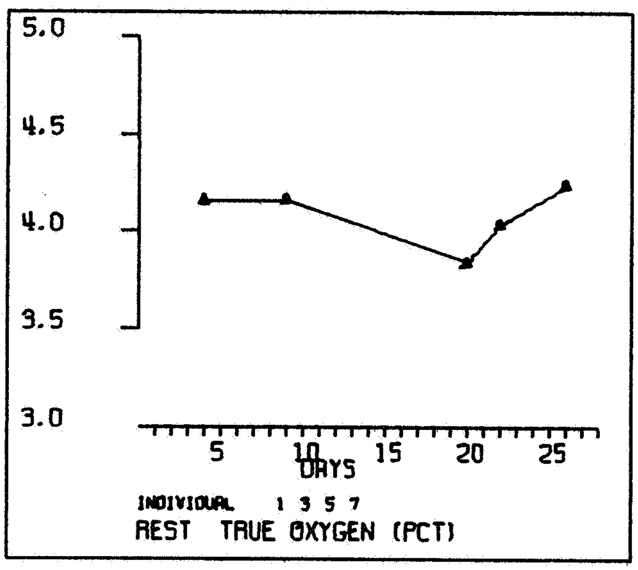
DAYS
INDIVIDUAL 2 4 6 8
REST RESP RATE PER MIN
* SOME APPROXIMATIONS INCLUDED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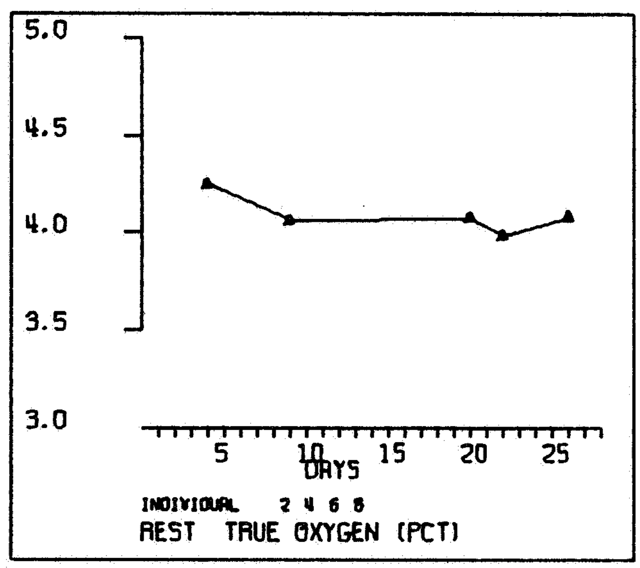
DAYS
INDIVIDUAL 1 3 5 7
REST TRUE OXYGEN (PCT)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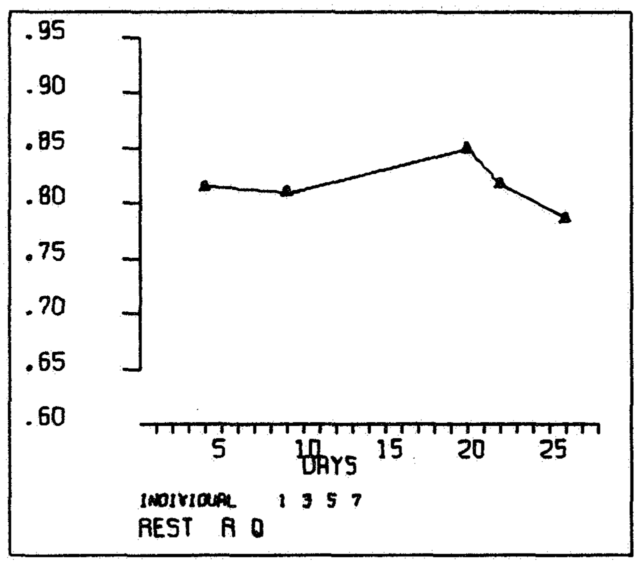
DAYS
INDIVIDUAL 2 4 6 8
REST TRUE OXYGEN (PCT)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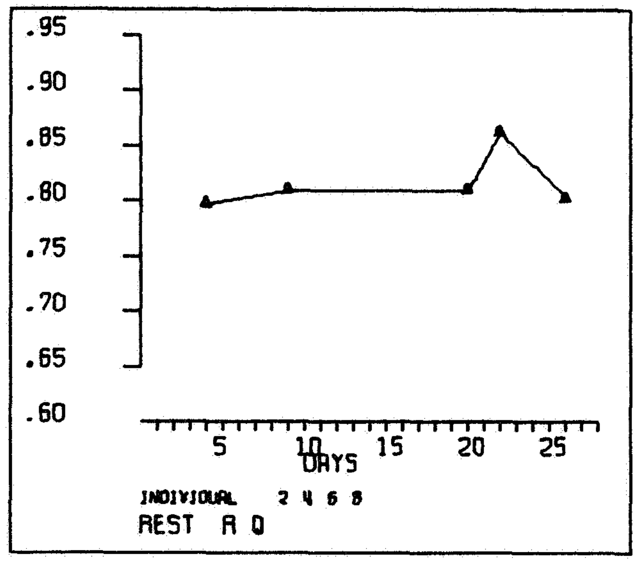
DAYS
INDIVIDUAL 1 3 5 7
REST R Q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DAYS
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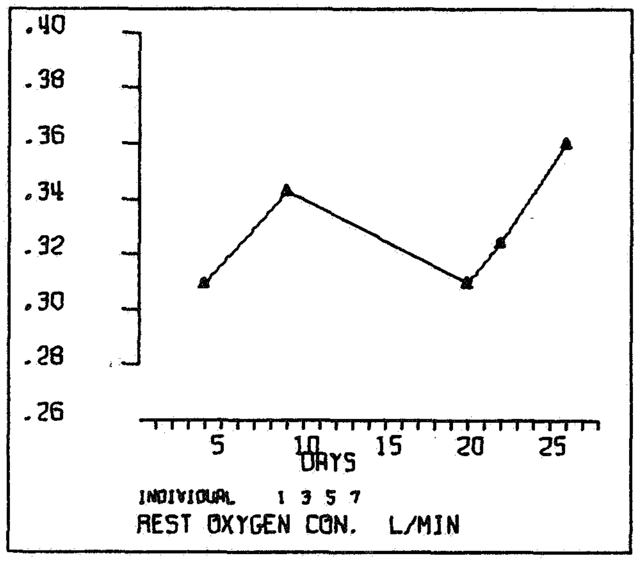
REST R Q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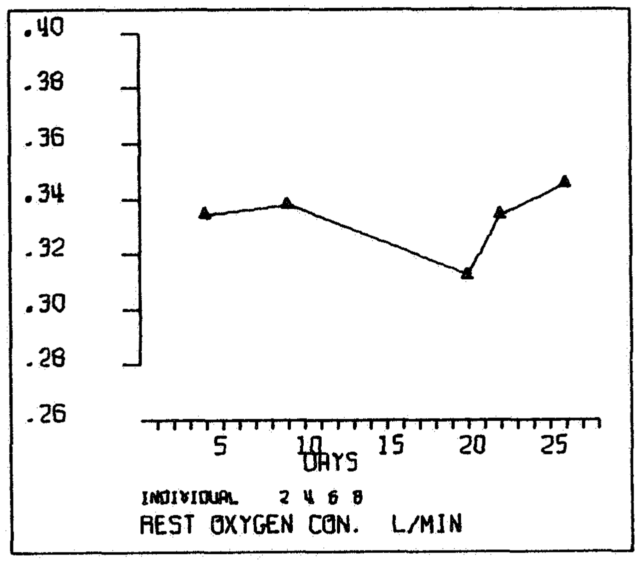
DAYS
INDIVIDUAL 1 3 5 7
REST OXYGEN CON. L/MIN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DAYS
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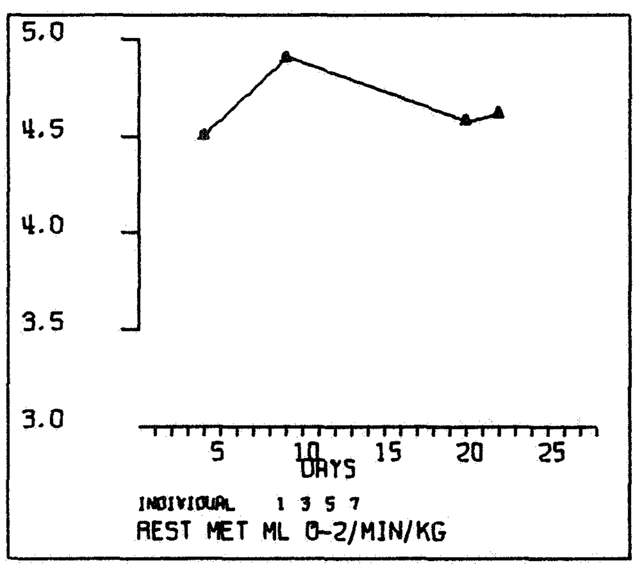
REST OXYGEN CON. L/MIN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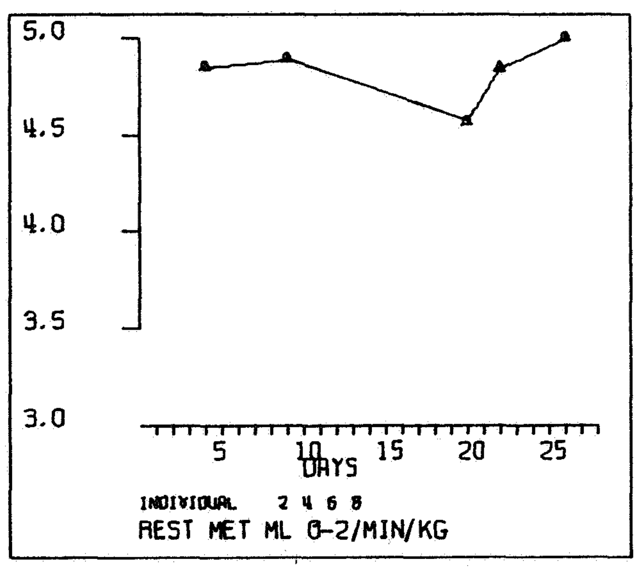
DAYS
INDIVIDUAL 1 3 5 7
REST MET ML O-2/MIN/KG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DAYS
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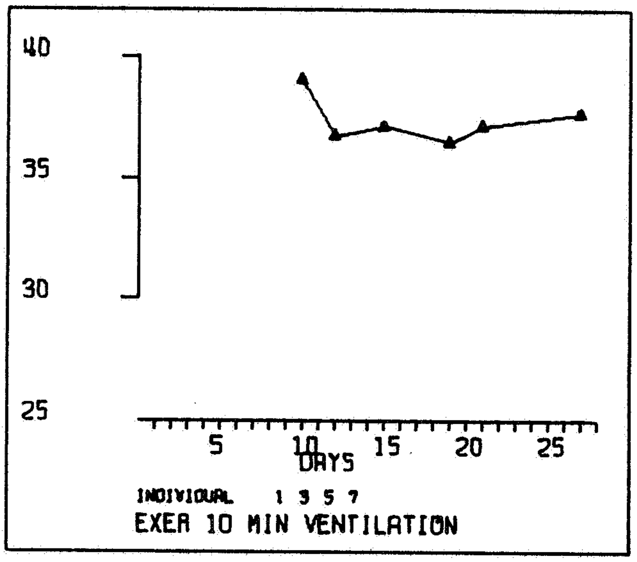
REST MET ML O-2/MIN/KG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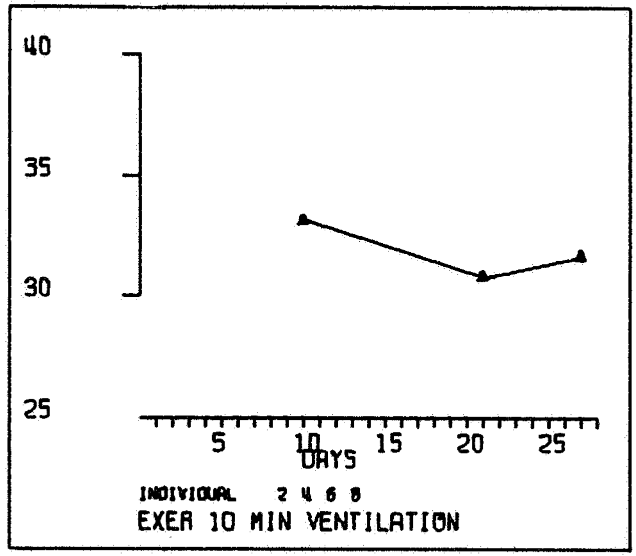
DAYS
INDIVIDUAL 1 3 5 7
EXER 10 MIN VENTILATION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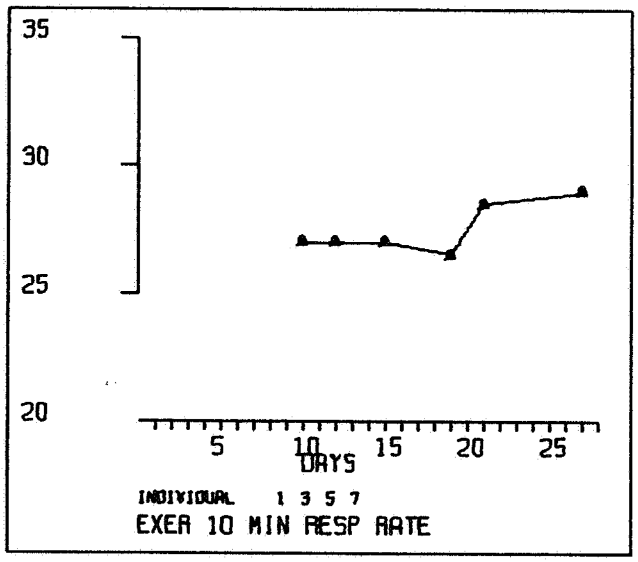
DAYS
INDIVIDUAL 2 4 6 8
EXER 10 MIN VENTILATION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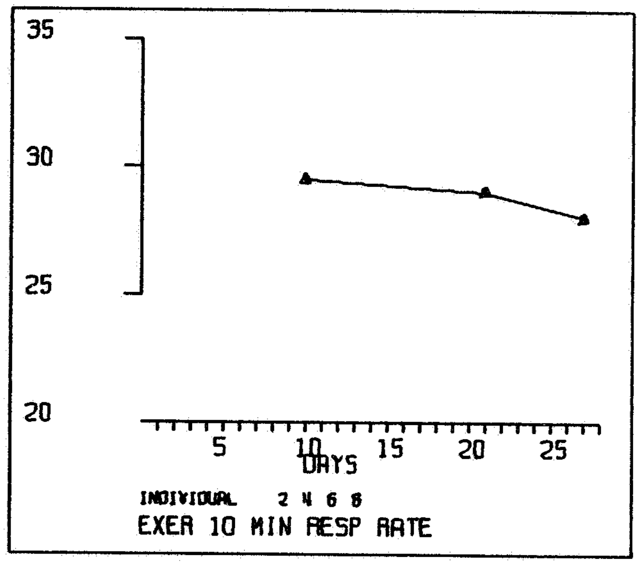
DAYS
INDIVIDUAL 1 3 5 7
EXER 10 MIN RESP RATE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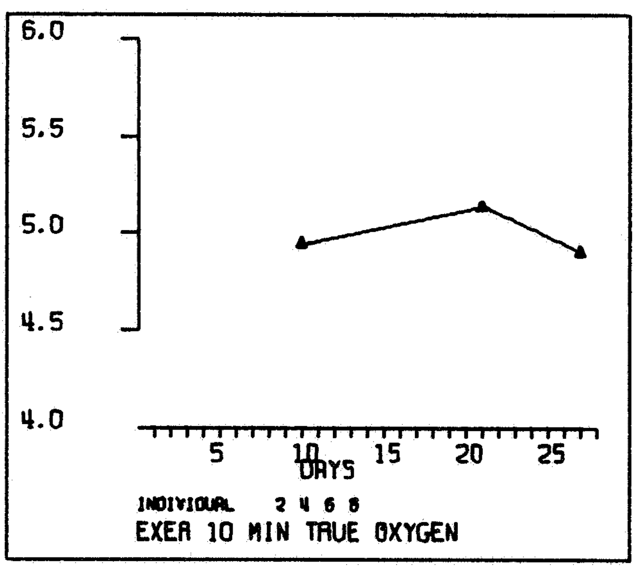
DAYS
INDIVIDUAL 2 4 6 8
EXER 10 MIN RESP RATE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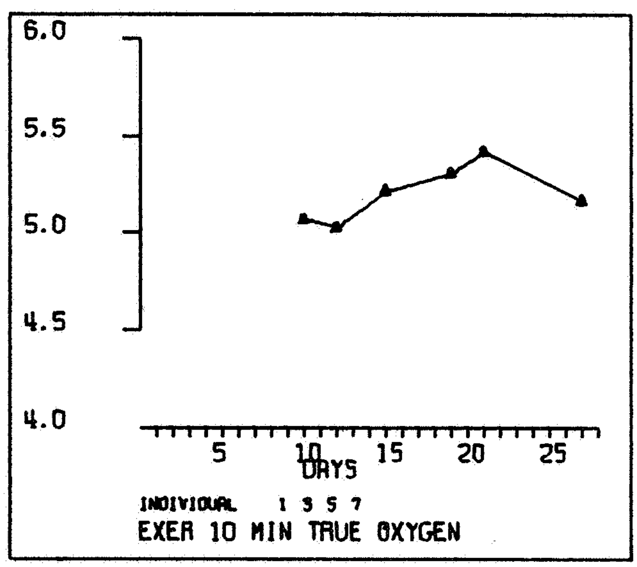
20
25
DAYS
INDIVIDUAL 2 4 6 8
EXER 10 MIN TRUE OXYGEN


6.0
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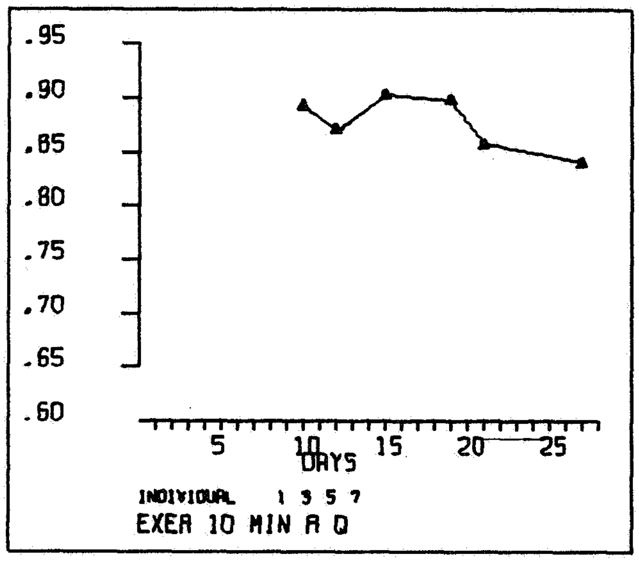
DAYS
INDIVIDUAL 1 3 5 7
EXER 10 MIN TRUE OXYGEN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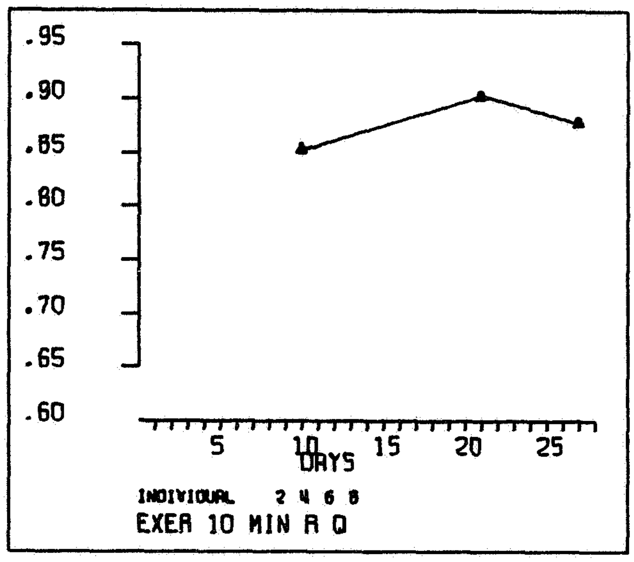
DAYS
INDIVIDUAL 1 3 5 7
EXER 10 MIN R Q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DAYS
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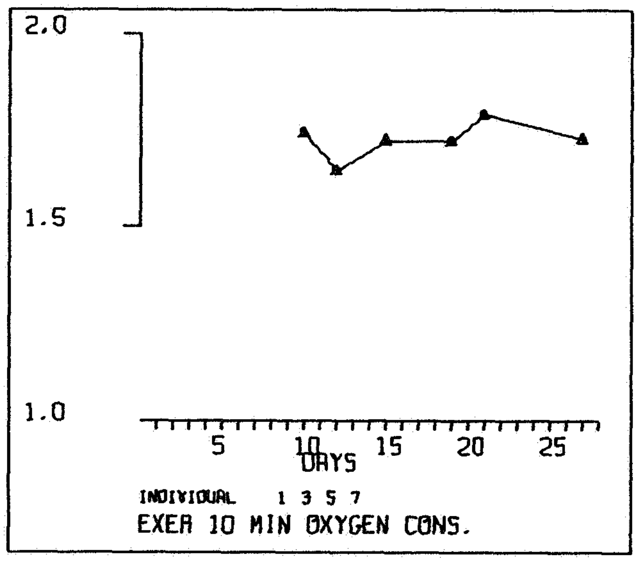
EXER 10 MIN R Q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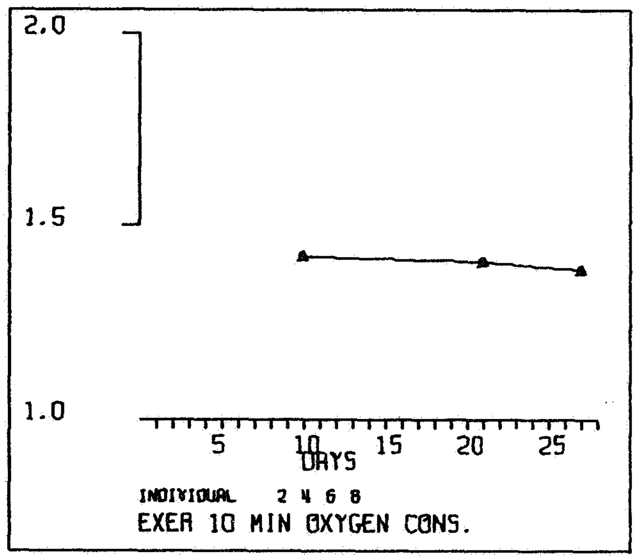
DAYS
INDIVIDUAL 1 3 5 7
EXER 10 MIN OXYGEN CONS.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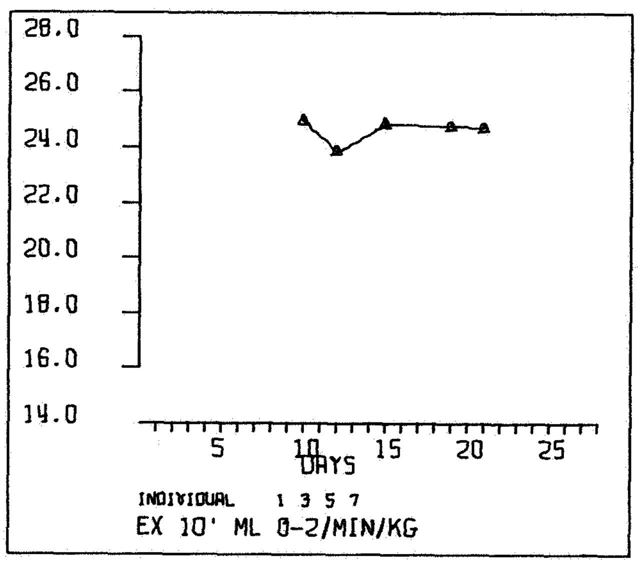
DAYS
INDIVIDUAL 2 4 6 8
EXER 10 MIN OXYGEN CONS.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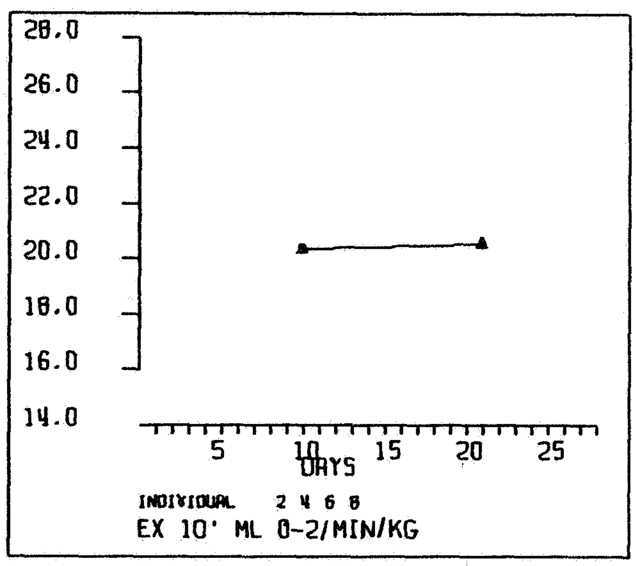
18.0
16.0
14.0
5 10 15 20 25
DAYS
INDIVIDUAL 1 3 5 7
EX 10' ML O-2/MIN/KG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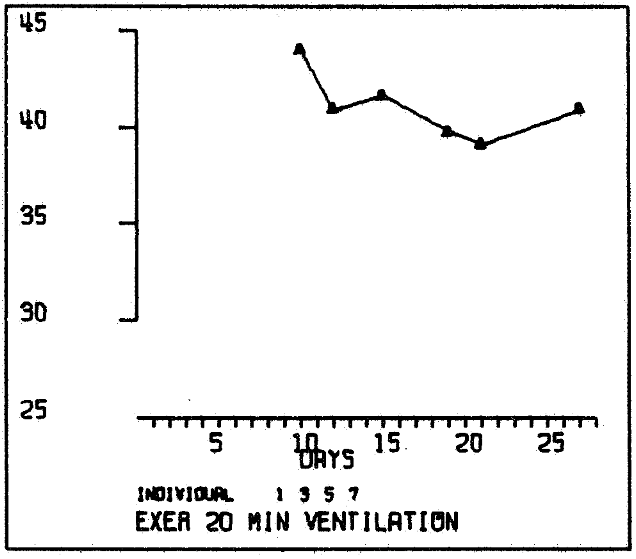
DAYS
INDIVIDUAL 2 4 6 8
EX 10' ML O-2/MIN/KG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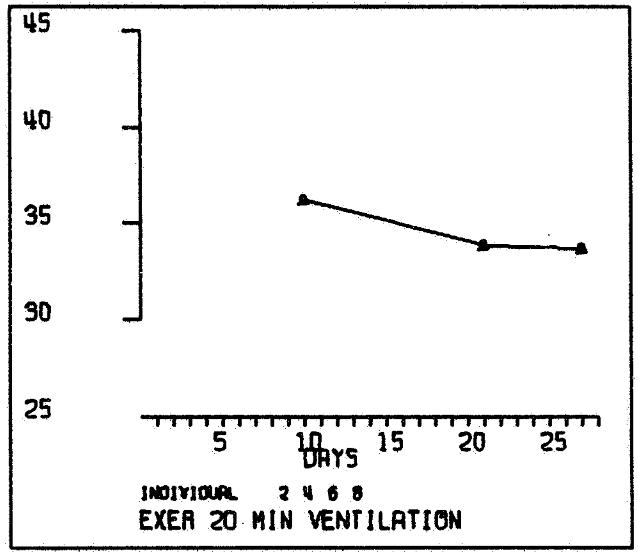
DAYS
INDIVIDUAL 1 3 5 7
EXER 20 MIN VENTILATION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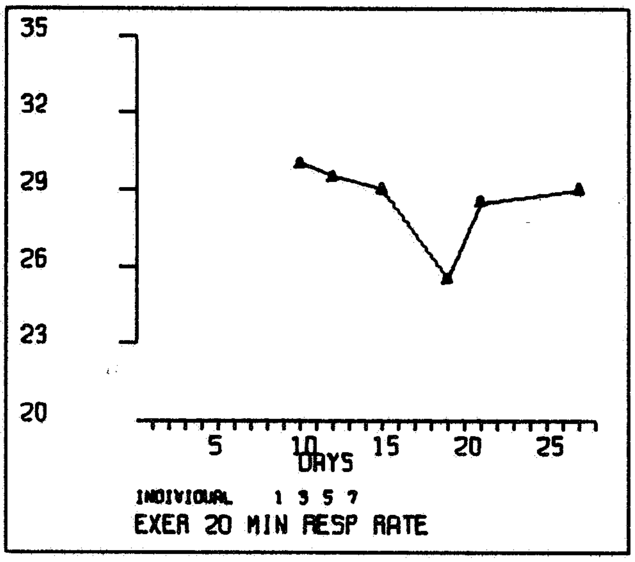
DAYS
INDIVIDUAL 2 4 6 8
EXER 20 MIN VENTILATION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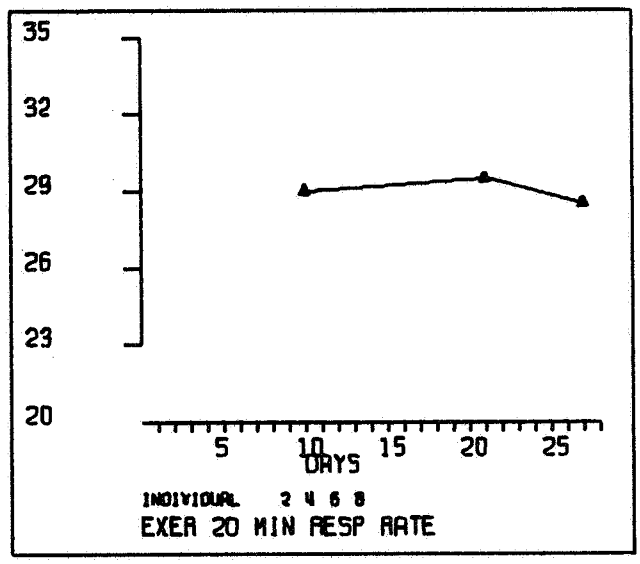
DAYS
INDIVIDUAL 1 3 5 7
EXER 20 MIN RESP RATE


35
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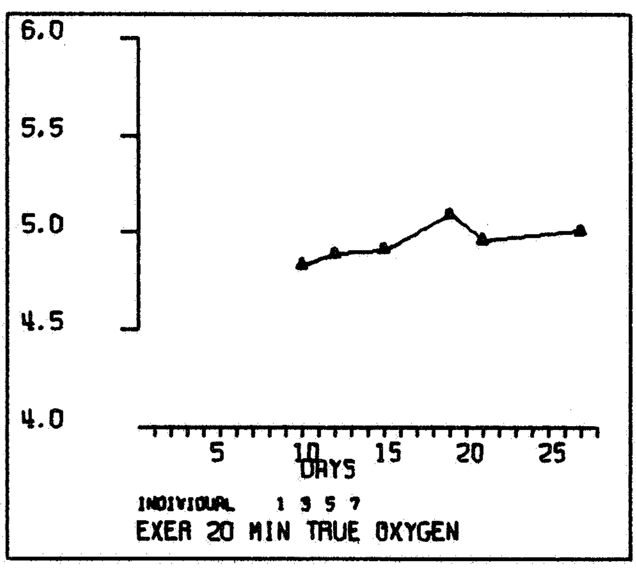
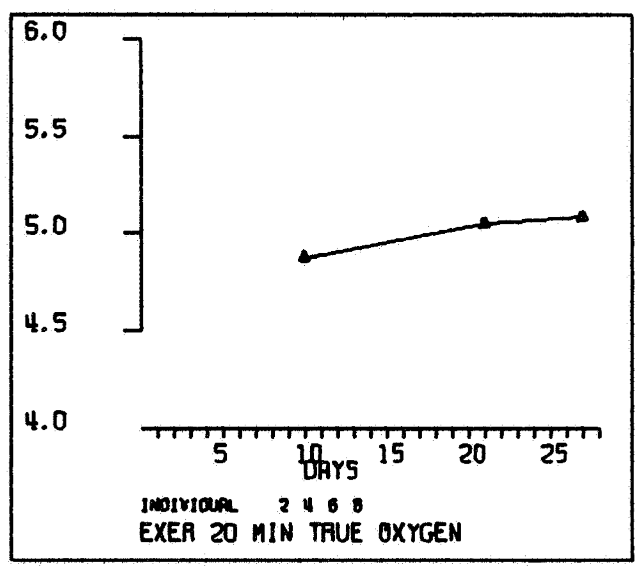
29
26
23
20
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
EXER 20 MIN RESP RATE


6.0
5.5
5.0
4.5
4.0
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
EXER 20 MIN TRUE OXYGEN


6.0
5.5
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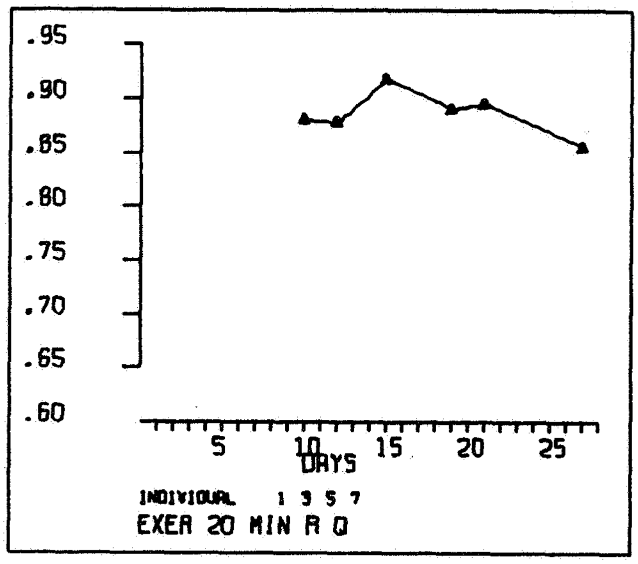
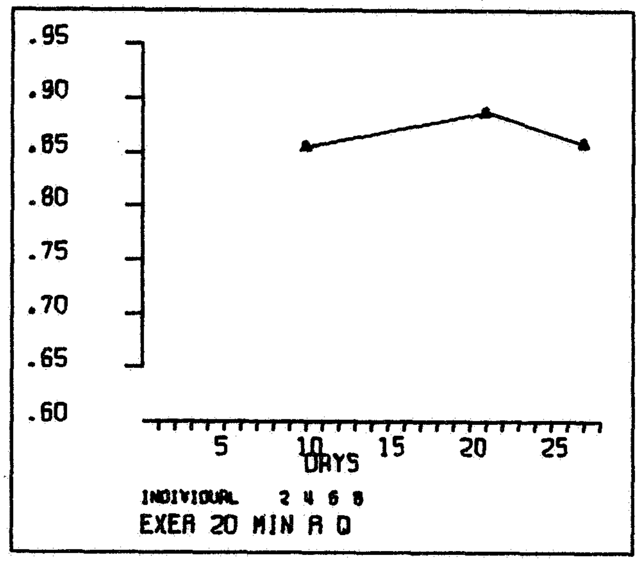
4.5
4.0
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
EXER 20 MIN TRUE OXYGEN


.95
.90
.85
.80
.75
.70
.65
.60
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
EXER 20 MIN R Q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.90
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.65
.60
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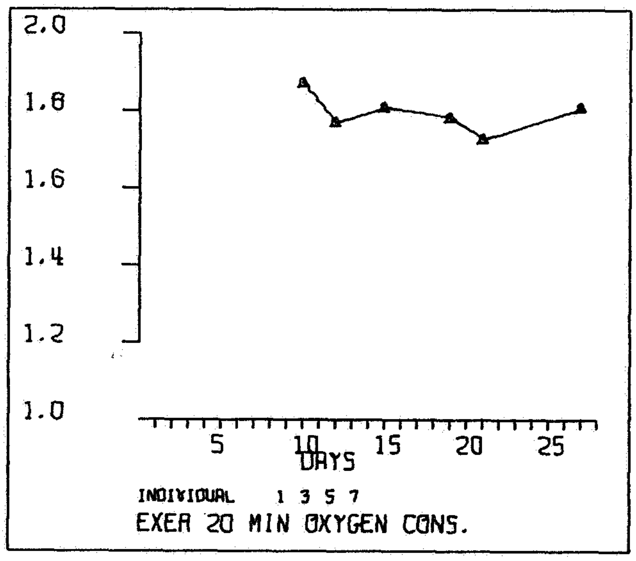
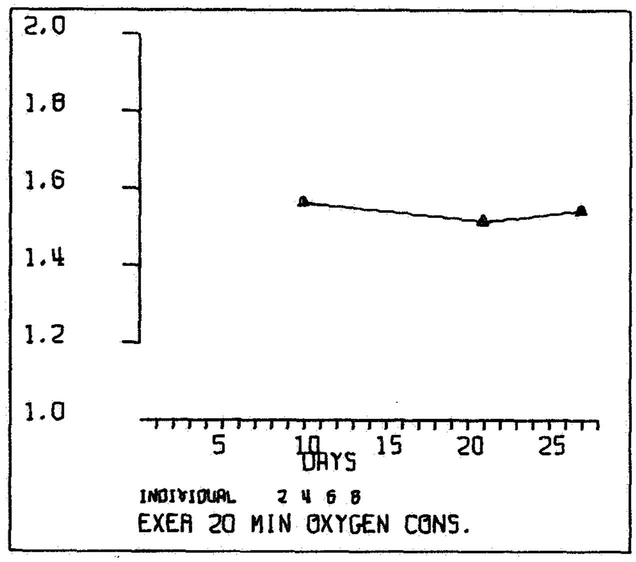
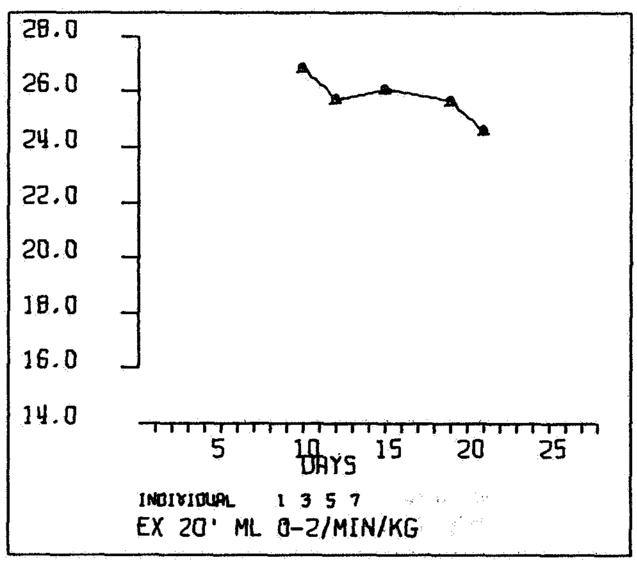
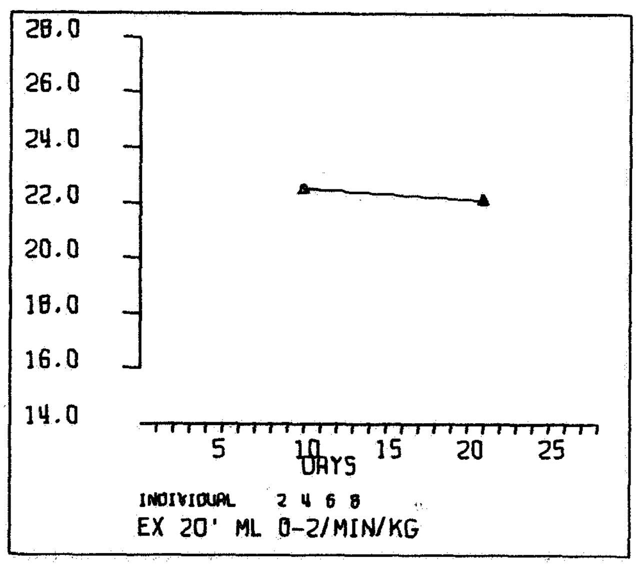
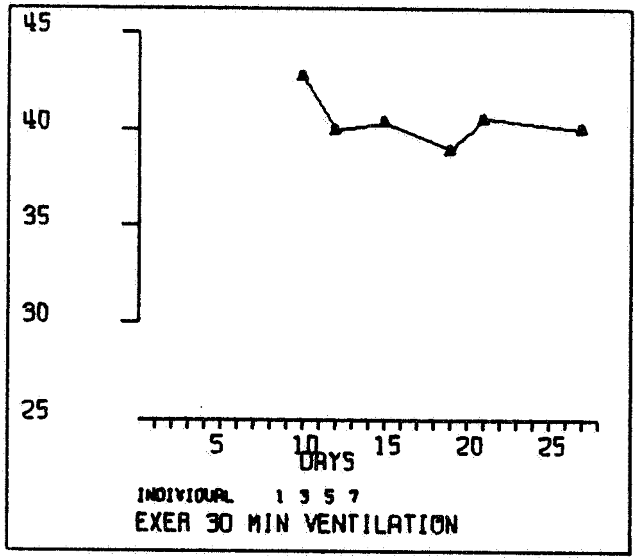
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
EXER 20 MIN R Q


2.0
1.8
1.6
1.4
1.2
1.0
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
EXER 20 MIN OXYGEN CONS.


2.0
1.8
1.6
1.4
1.2
1.0
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
EXER 20 MIN OXYGEN CONS.


28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
EX 20' ML O-2/MIN/KG


28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
EX 20' ML O-2/MIN/KG


45
40
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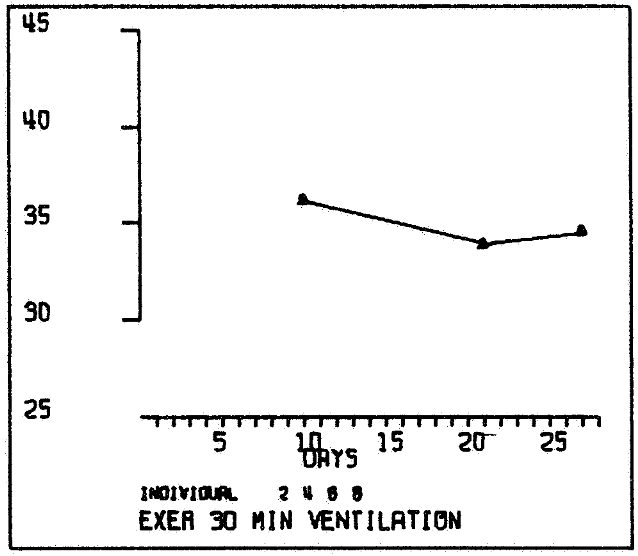
30
25
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
EXER 30 MIN VENTILATION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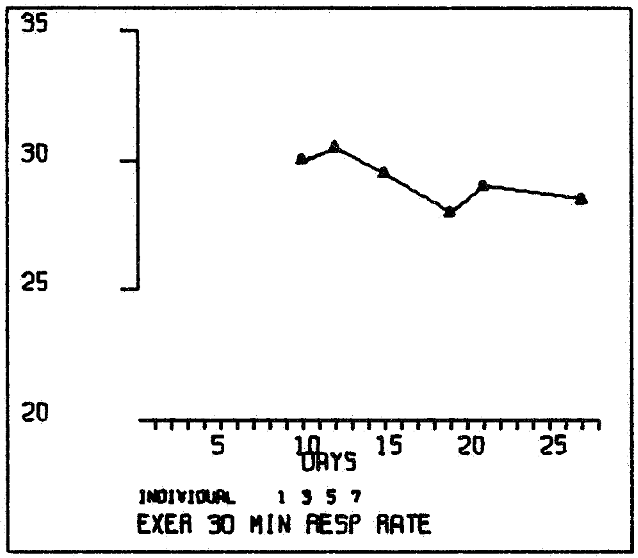
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
EXER 30 MIN VENTILATION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30
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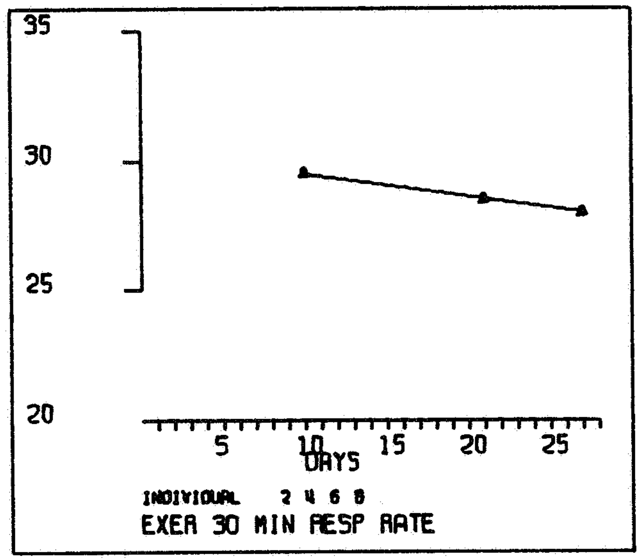
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
EXER 30 MIN RESP RATE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10
15
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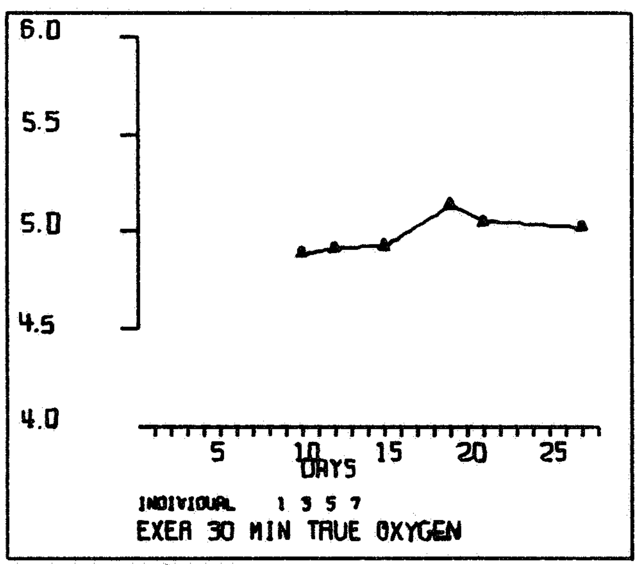
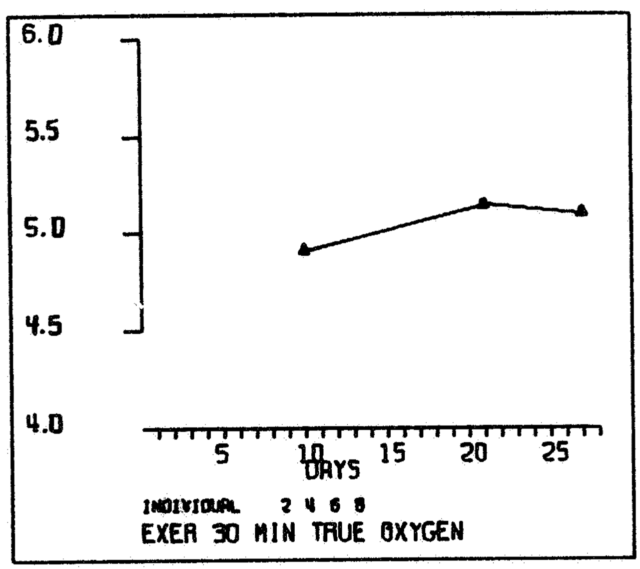
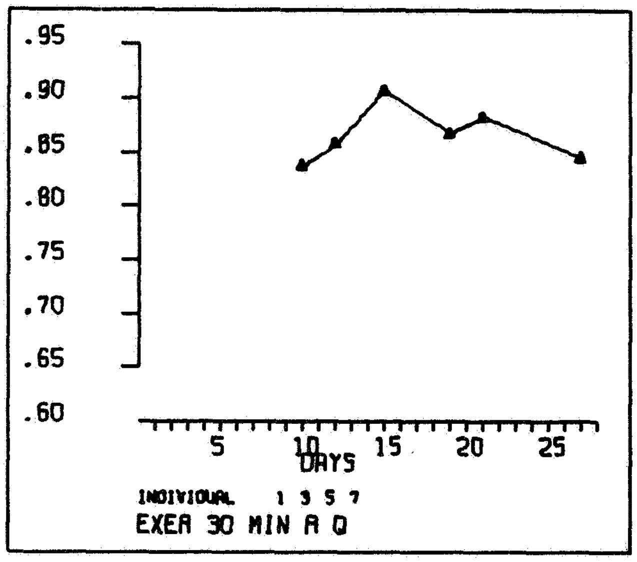
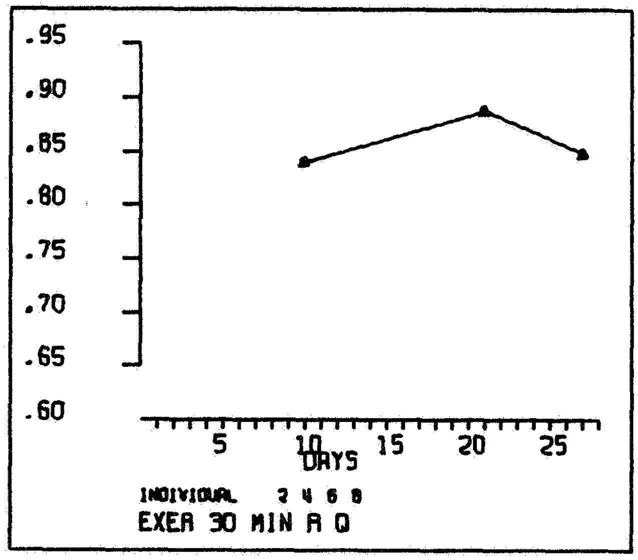
25
DAYS
INDIVIDUAL 2 4 6 8
EXER 30 MIN RESP RATE


6.0
5.5
5.0
4.5
4.0
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
EXER 30 MIN TRUE OXYGEN


6.0
5.5
5.0
4.5
4.0
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
EXER 30 MIN TRUE OXYGEN



.95
.90
.85
.80
.75
.70
.65
.60
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
EXER 30 MIN R Q



.95
.90
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.65
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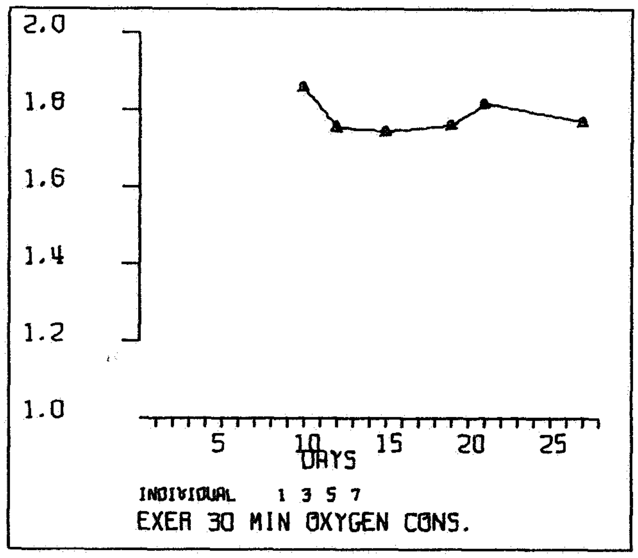
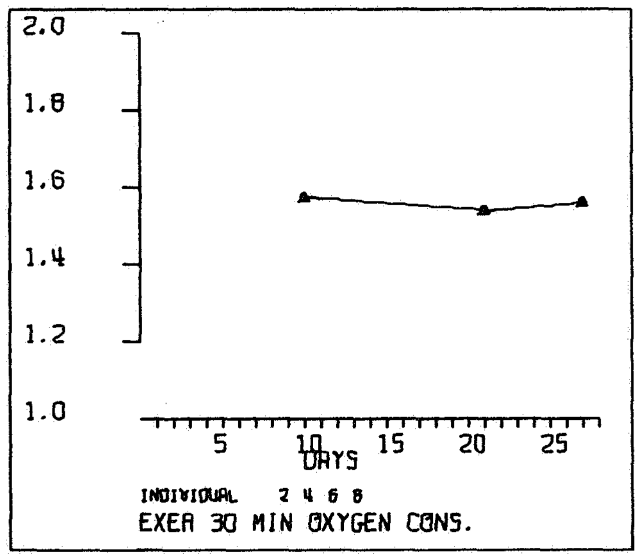
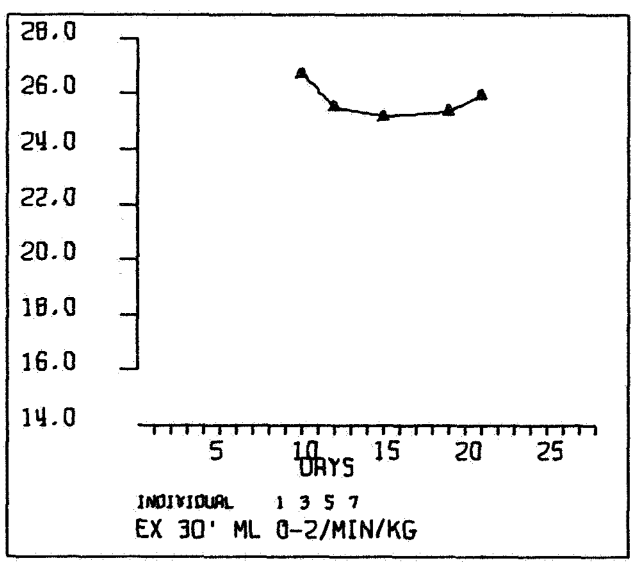
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
EXER 30 MIN R Q



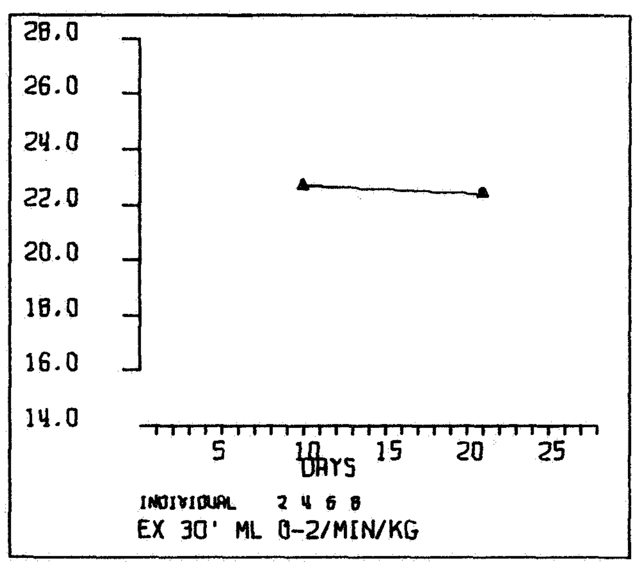
2.0
1.8
1.6
1.4
1.2
1.0
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
EXER 30 MIN OXYGEN CONS.



2.0
1.8
1.6
1.4
1.2
1.0
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
EXER 30 MIN OXYGEN CONS.



28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
EX 30' ML O-2/MIN/KG



28.0
26.0
24.0
22.0
20.0
18.0
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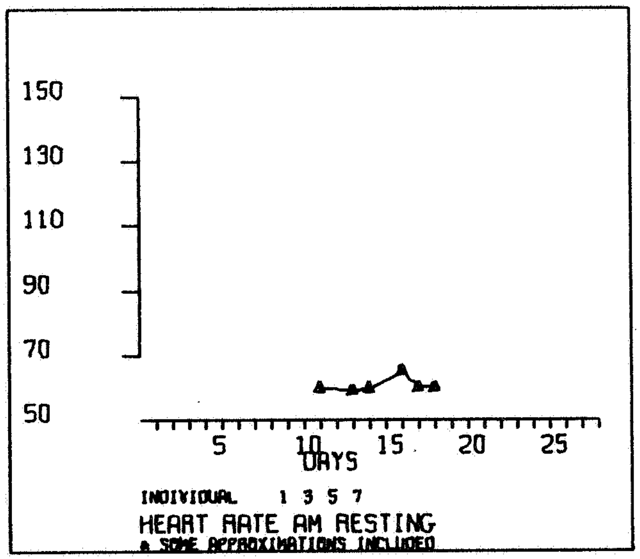
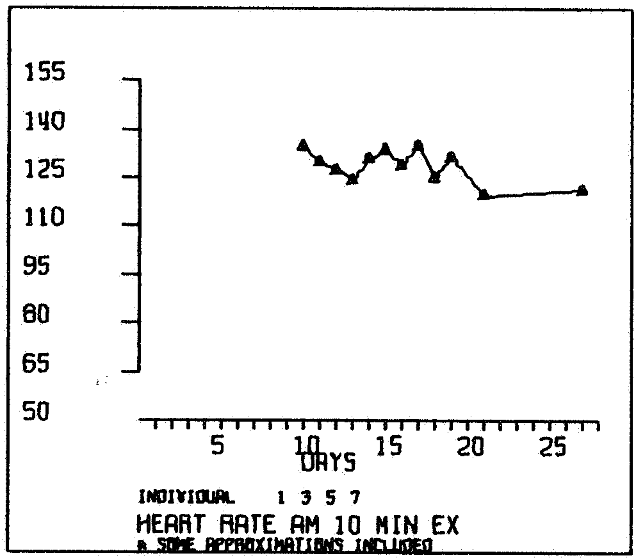
14.0
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
EX 30' ML O-2/MIN/KG



150
130
110
90
70
50
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
HEART RATE AM RESTING
* SOME APPROXIMATIONS INCLUDED



155
140
125
110
95
80
65
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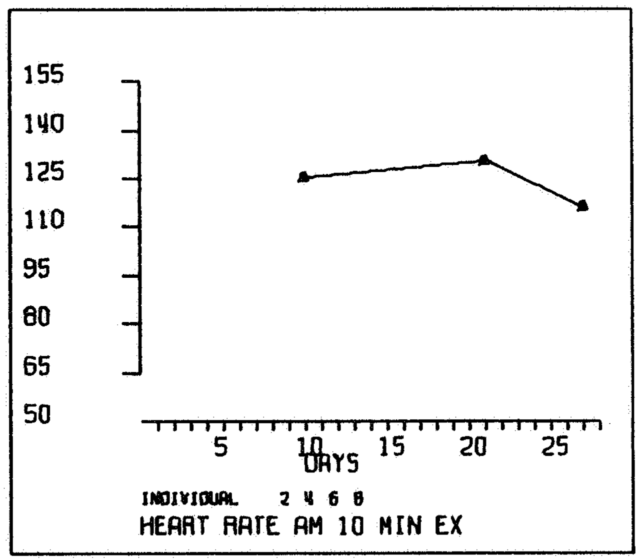
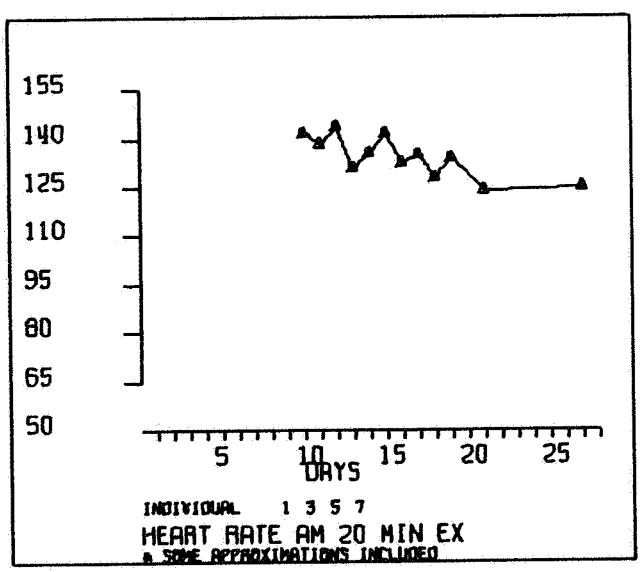
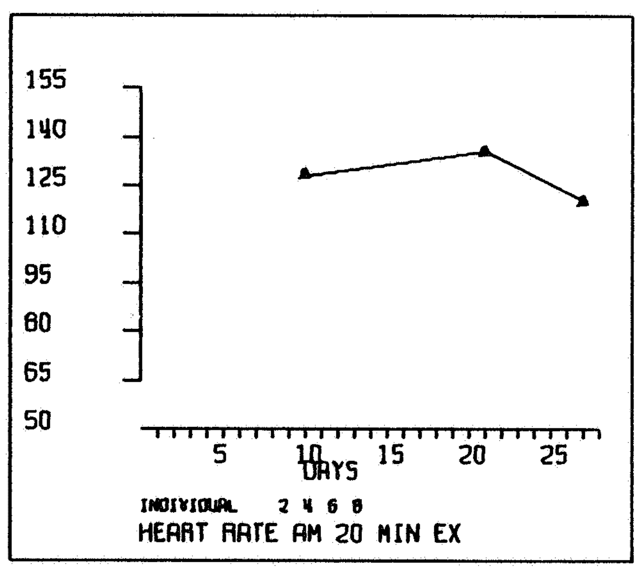
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
HEART RATE AM 10 MIN EX
* SOME APPROXIMATIONS INCLUDED



155
140
125
110
95
80
65
50
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
HEART RATE AM 10 MIN EX



155
140
125
110
95
80
65
50
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
HEART RATE AM 20 MIN EX
* SOME APPROXIMATIONS INCLUDED



155
140
125
110
95
80
65
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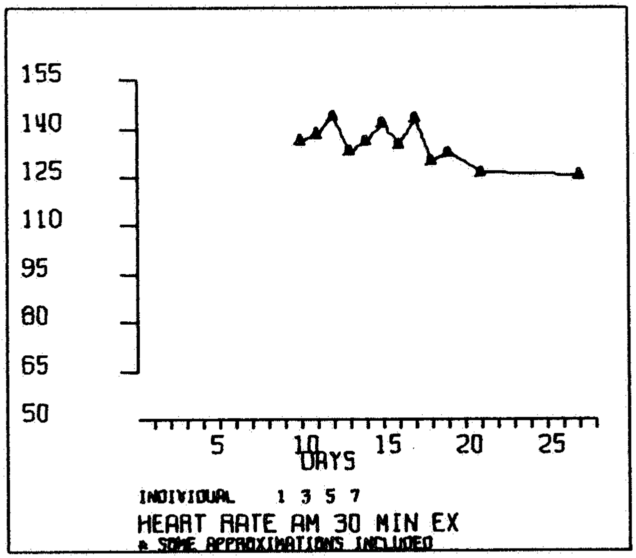
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
HEART RATE AM 20 MIN EX


155
140
125
110
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80
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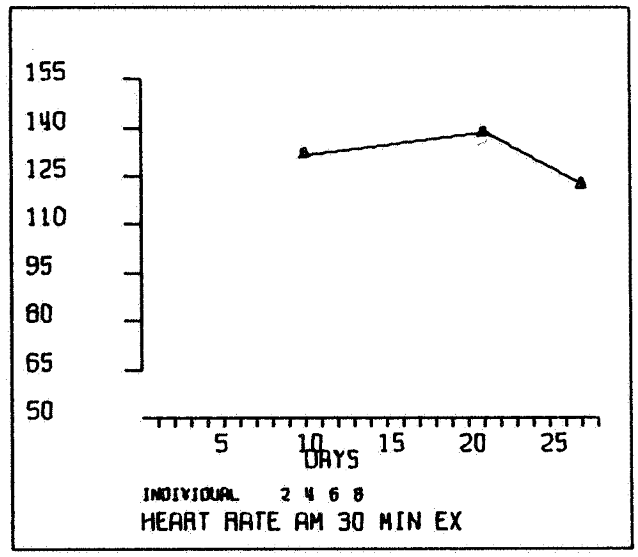
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
HEART RATE AM 30 MIN EX
* SOME APPROXIMATIONS INCLUDED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125
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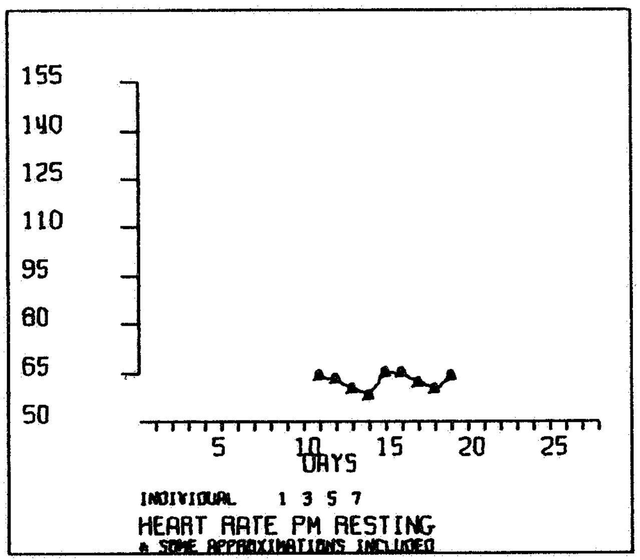
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
HEART RATE AM 30 MIN EX


155
140
125
110
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65
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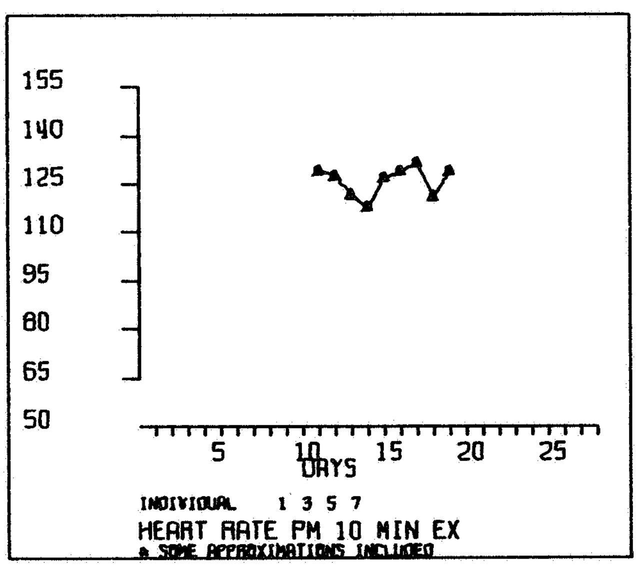
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
HEART RATE PM RESTING
* SOME APPROXIMATIONS INCLUDED


155
140
125
110
95
80
65
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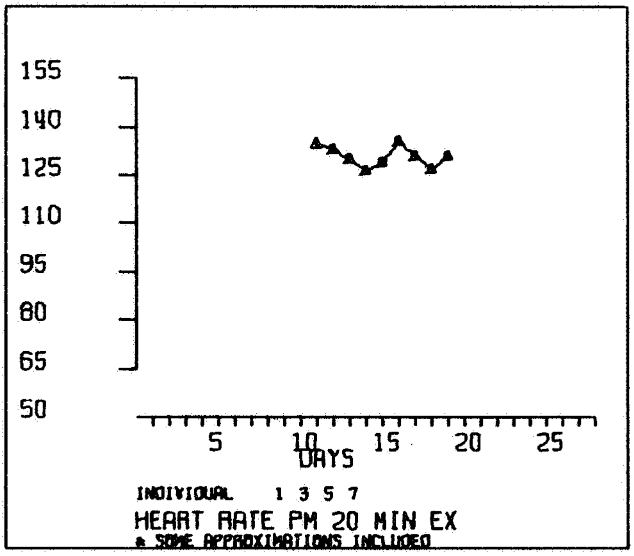
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
HEART RATE PM 10 MIN EX
* SOME APPROXIMATIONS INCLUDED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140
125
110
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65
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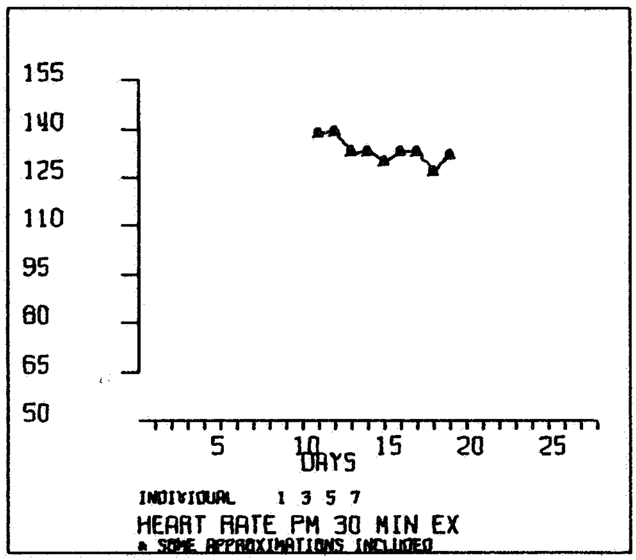
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
HEART RATE PM 20 MIN EX
* SOME APPROXIMATIONS INCLUDED


155
140
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110
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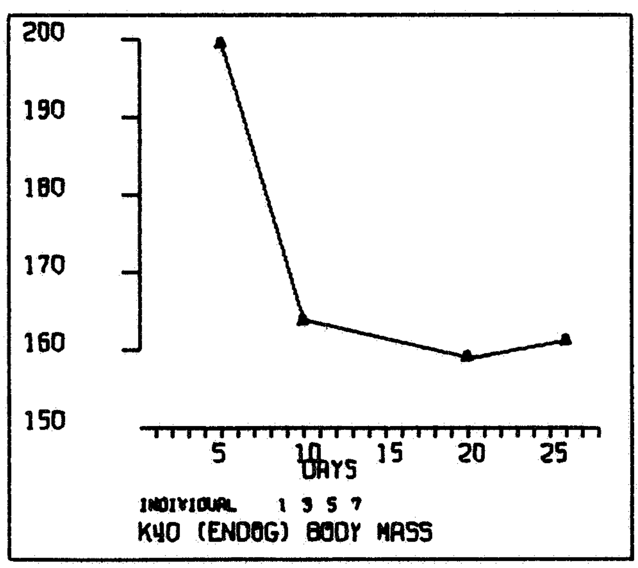
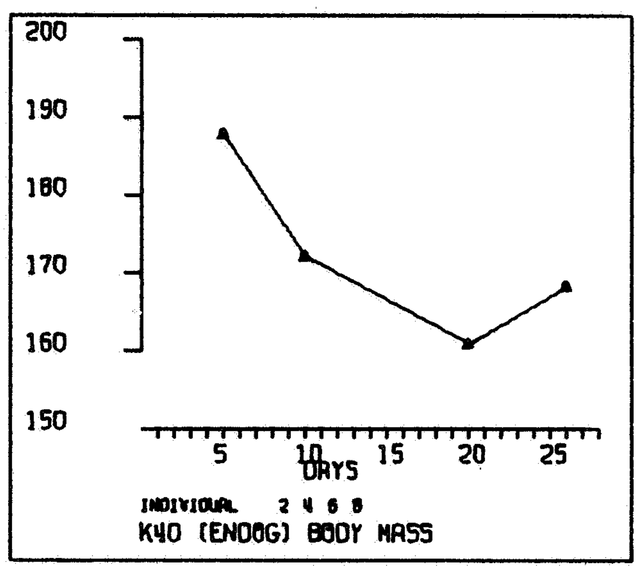
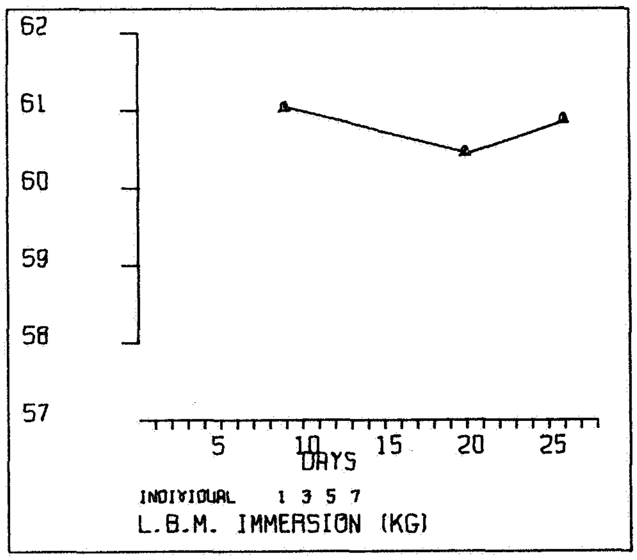
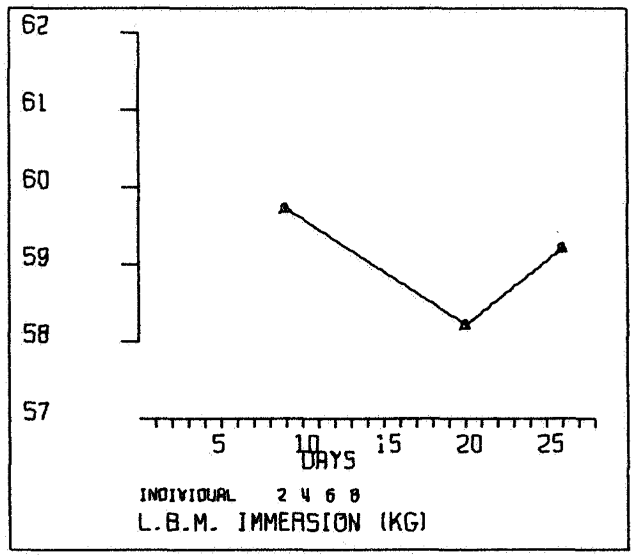
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
HEART RATE PM 30 MIN EX
* SOME APPROXIMATIONS INCLUDED


200
190
180
170
160
150
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
K40 (ENDOG) BODY MASS


200
190
180
170
160
150
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
K40 (ENDOG) BODY MASS


62
61
60
59
58
57
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
L.B.M. IMMERSION (KG)


62
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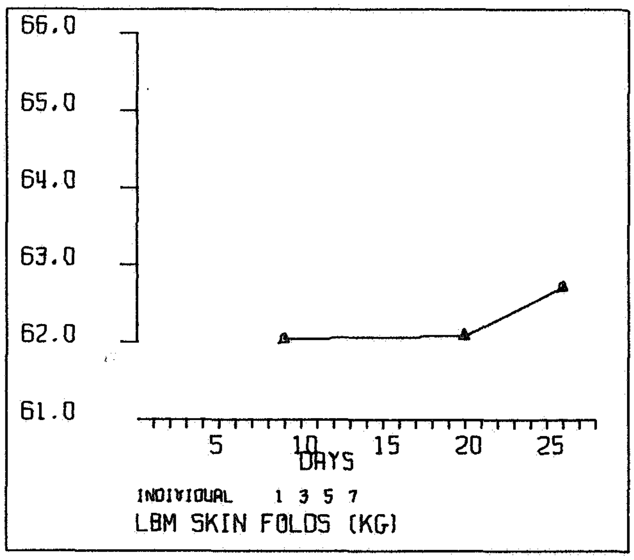
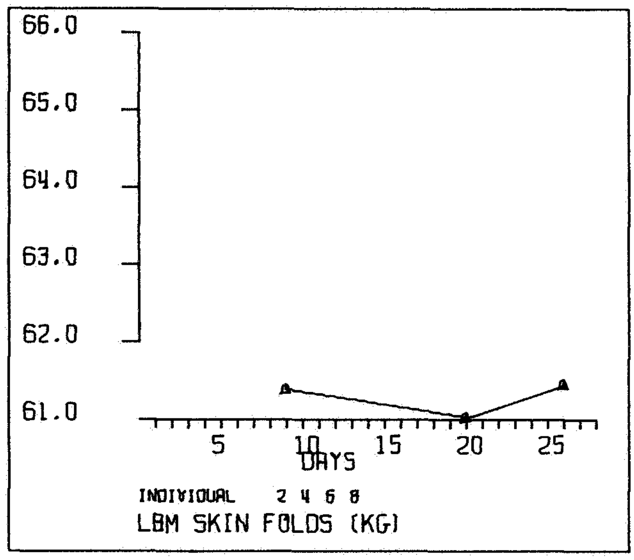
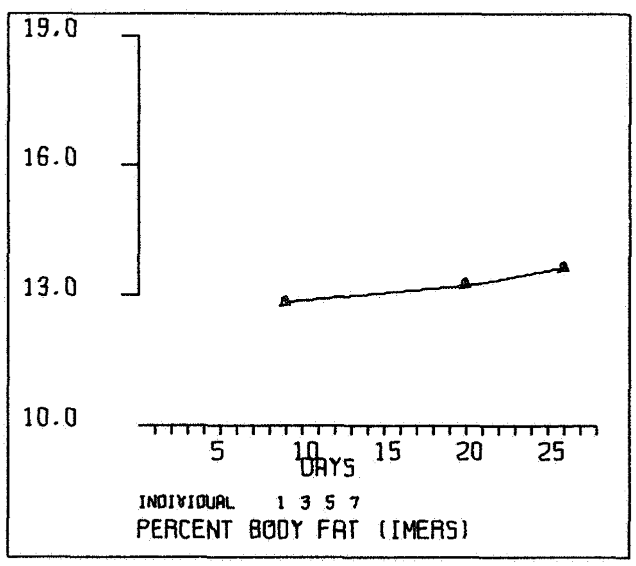
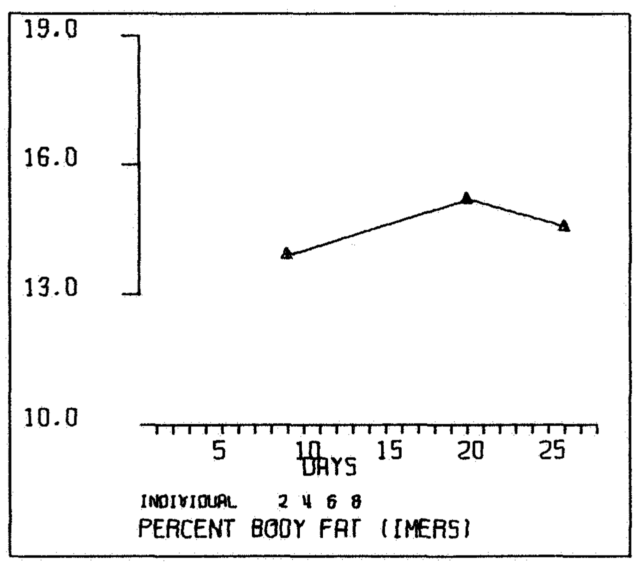
25
DAYS
INDIVIDUAL 2 4 6 8
L.B.M. IMMERSION (KG)


66.0
65.0
64.0
63.0
62.0
61.0
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
LBM SKIN FOLDS (KG)


66.0
65.0
64.0
63.0
62.0
61.0
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
LBM SKIN FOLDS (KG)


19.0
16.0
13.0
10.0
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
PERCENT BODY FAT (IMERS)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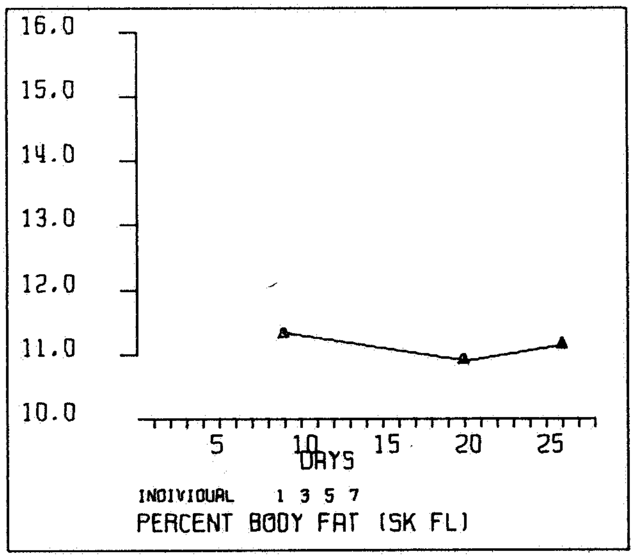
16.0
13.0
10.0
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
PERCENT BODY FAT (IMERS)


16.0
15.0
14.0
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12.0
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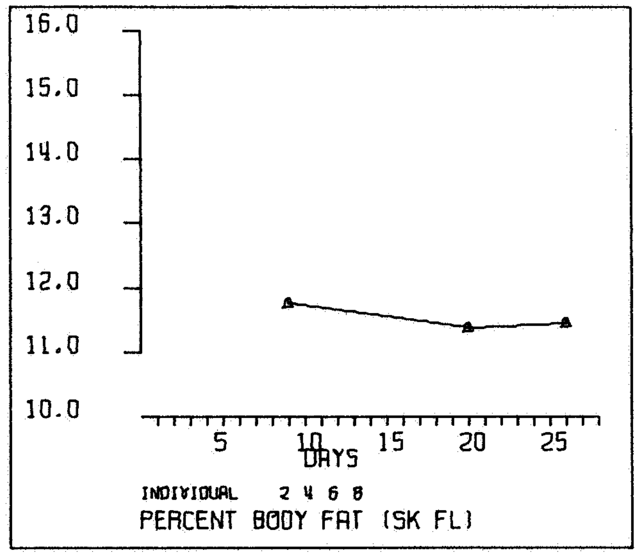
10.0
5
10
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
PERCENT BODY FAT (SK FL)


16.0
15.0
14.0
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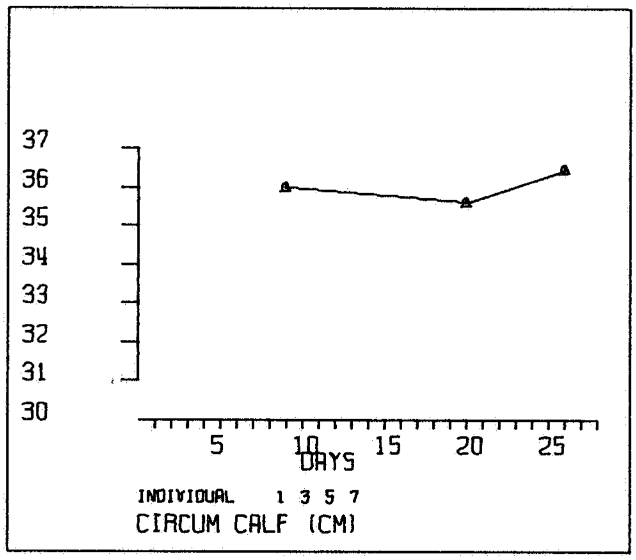
11.0
10.0
5
10
15
20
25
DAYS
INDIVIDUAL 2 4 6 8
PERCENT BODY FAT (SK FL)


37
36
35
34
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32
31
30
5
10
15
20
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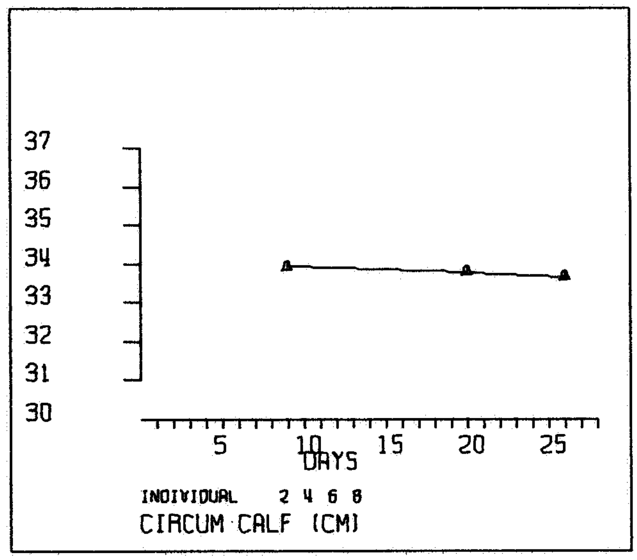
DAYS
INDIVIDUAL 1 3 5 7
CIRCUM CALF (CM)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20
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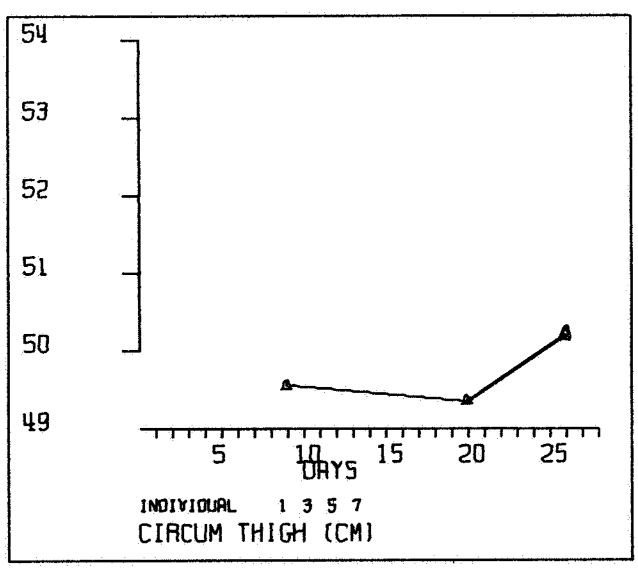
DAYS
INDIVIDUAL 2 4 6 8
CIRCUM CALF (CM)


54
53
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51
50
49
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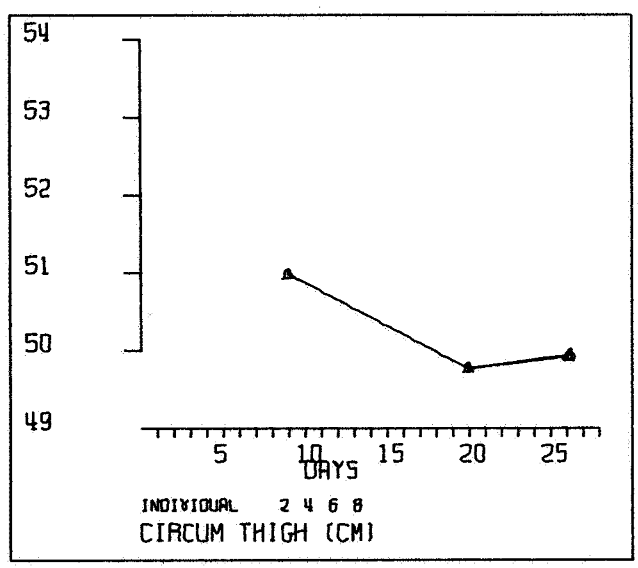
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
CIRCUM THIGH (CM)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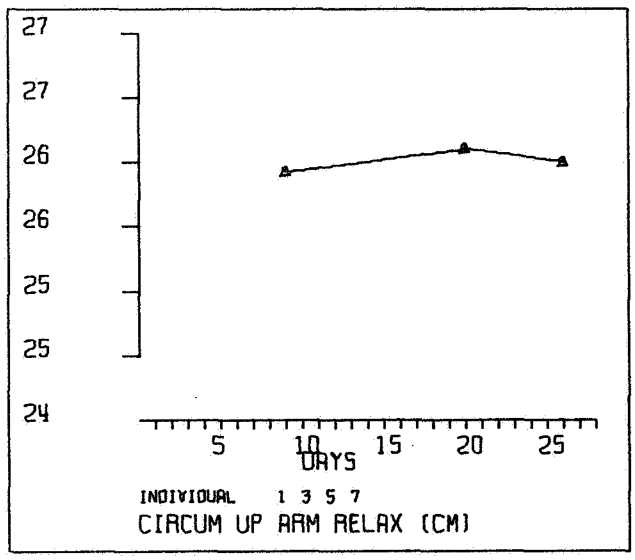
DAYS
INDIVIDUAL 2 4 6 8
CIRCUM THIGH (CM)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26
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24
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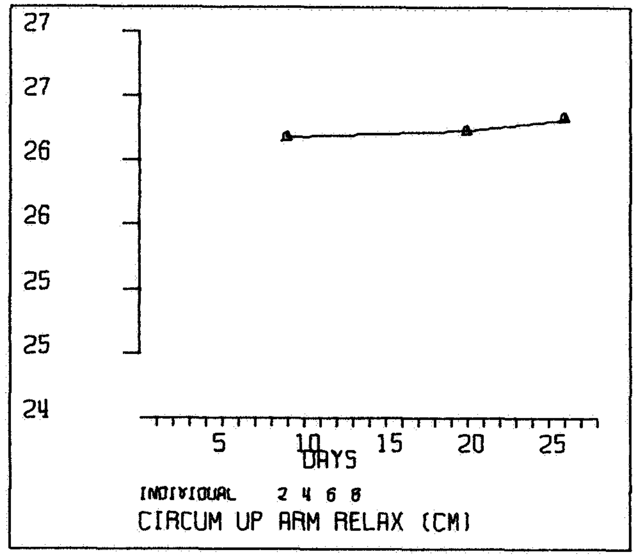
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
CIRCUM UP ARM RELAX (CM)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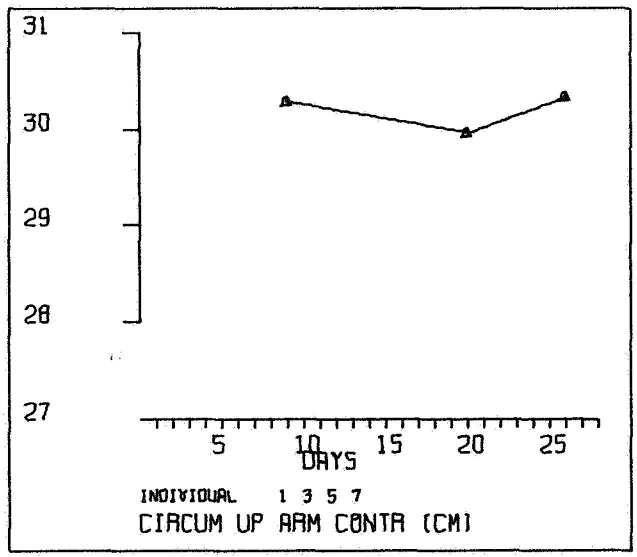
20
25
DAYS
INDIVIDUAL 2 4 6 8
CIRCUM UP ARM RELAX (CM)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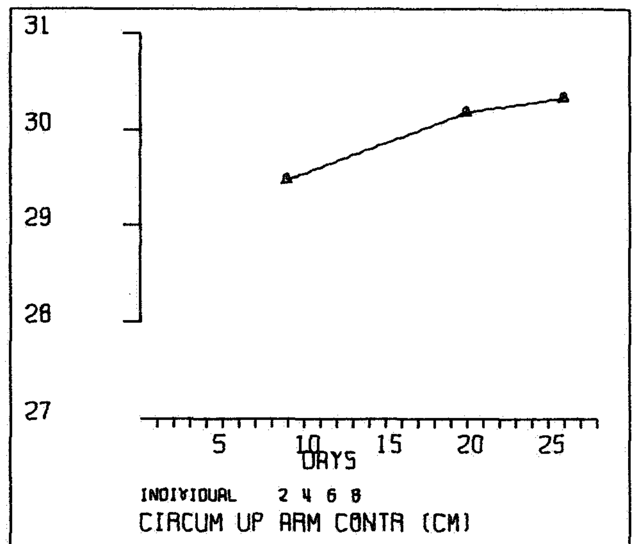
25
DAYS
INDIVIDUAL 1 3 5 7
CIRCUM UP ARM CONTR (CM)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DAYS
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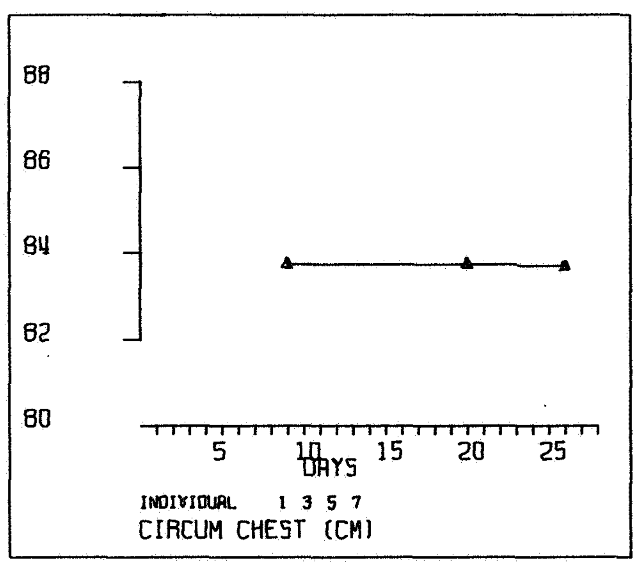
CIRCUM UP ARM CONTR (CM)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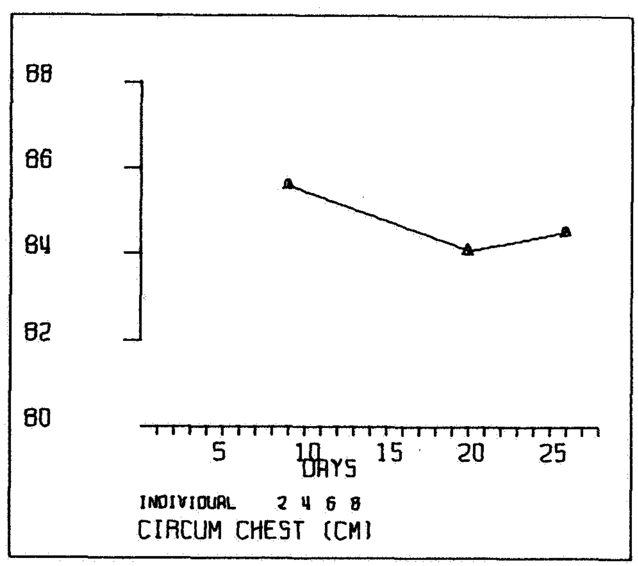
DAYS
INDIVIDUAL 1 3 5 7
CIRCUM CHEST (CM)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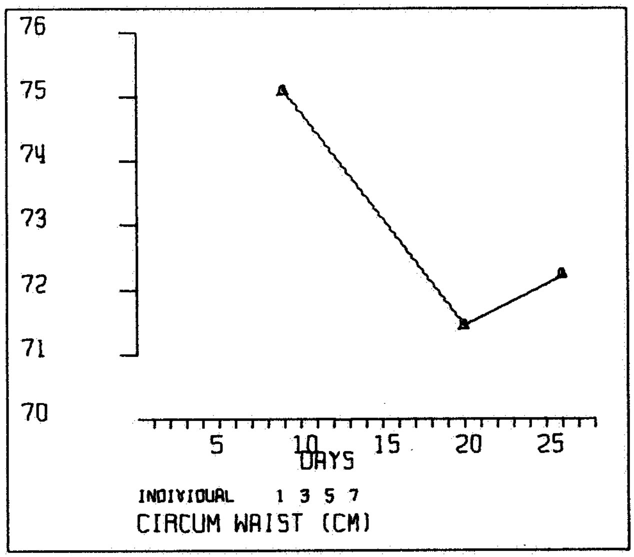
DAYS
INDIVIDUAL 2 4 6 8
CIRCUM CHEST (CM)



76
75
74
73
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70
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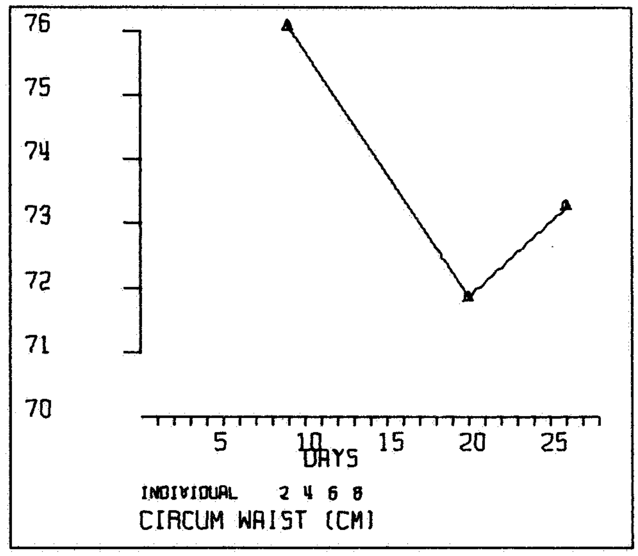
DAYS
INDIVIDUAL 1 3 5 7
CIRCUM WAIST (CM)



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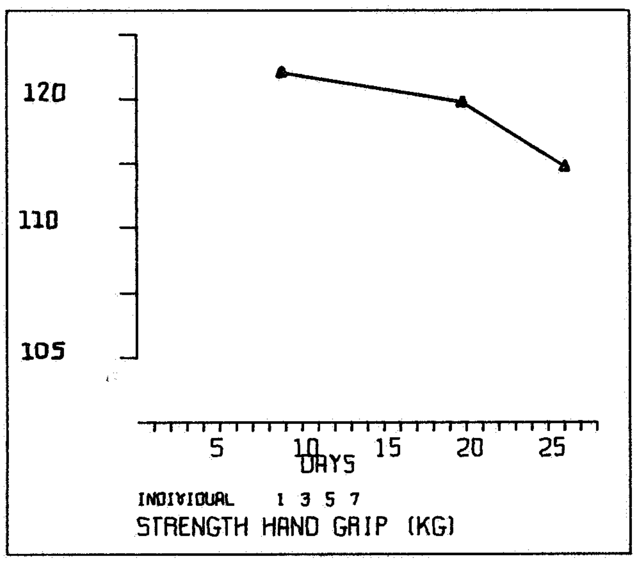
DAYS
INDIVIDUAL 2 4 6 8
CIRCUM WAIST (CM)



120
110
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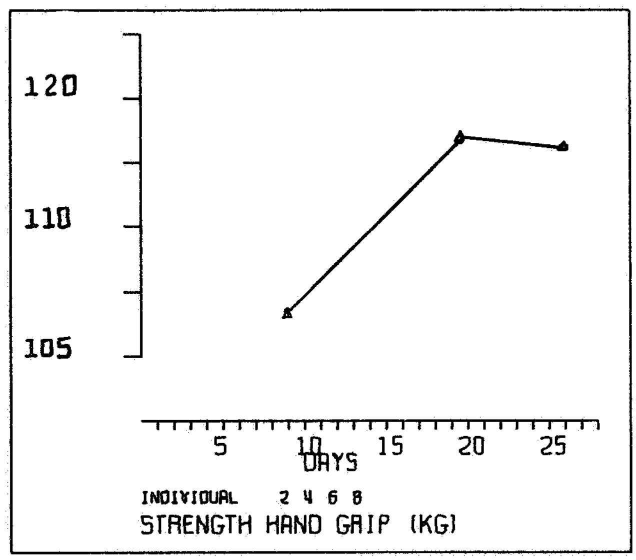
DAYS
INDIVIDUAL 1 3 5 7
STRENGTH HAND GRIP (KG)



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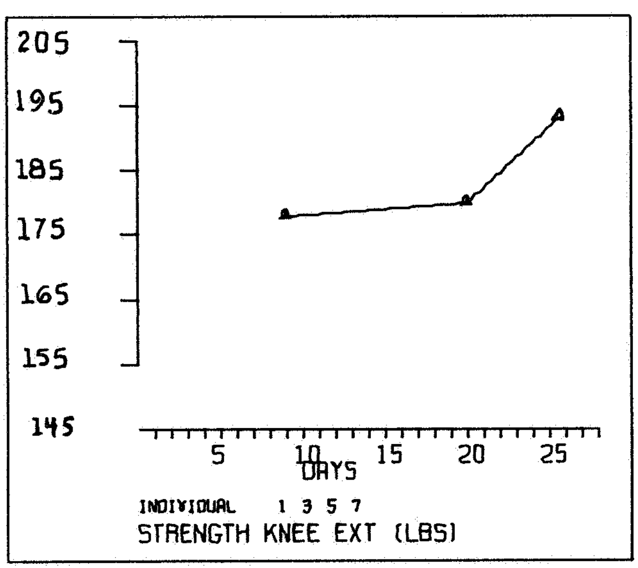
DAYS
INDIVIDUAL 2 4 6 8
STRENGTH HAND GRIP (KG)



205
195
185
175
165
155
145
5
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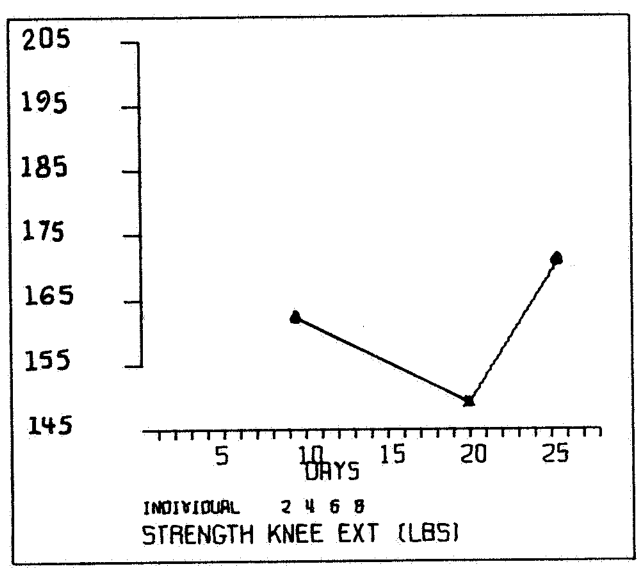
15
20
25
DAYS
INDIVIDUAL 1 3 5 7
STRENGTH KNEE EXT (LBS)



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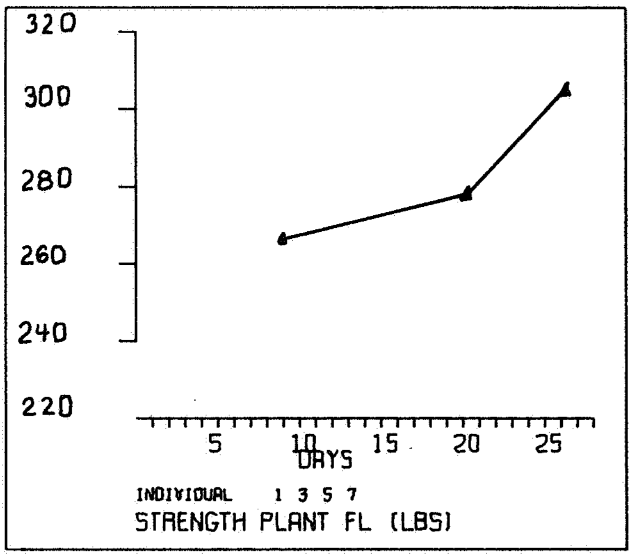
DAYS
INDIVIDUAL 2 4 6 8
STRENGTH KNEE EXT (LBS)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220
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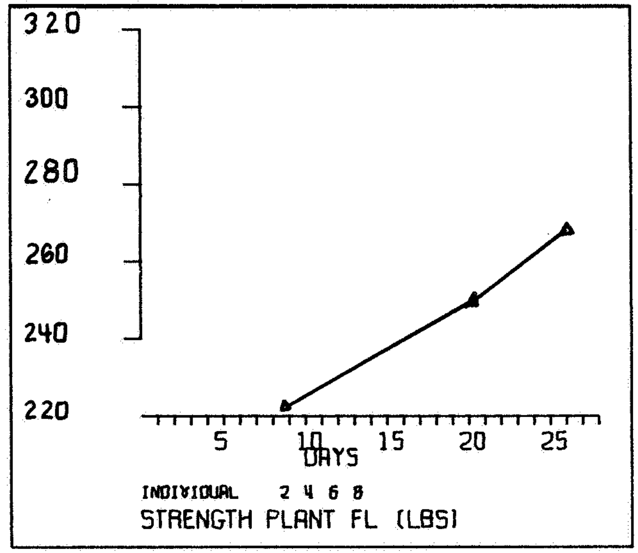
DAYS
INDIVIDUAL 1 3 5 7
STRENGTH PLANT FL (LBS)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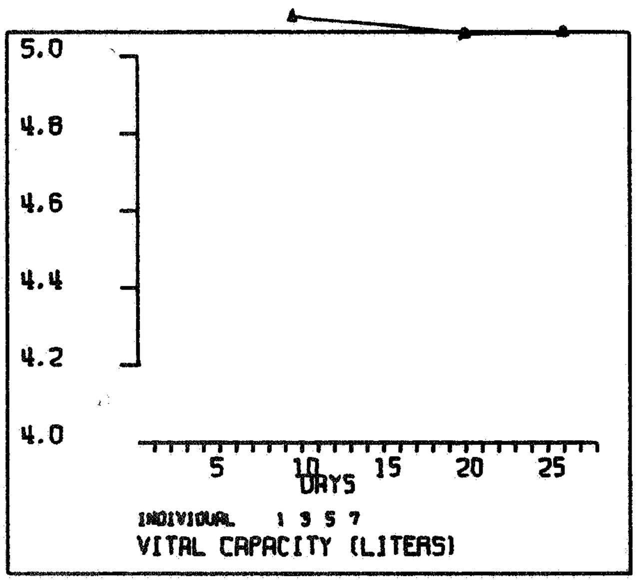
DAYS
INDIVIDUAL 2 4 6 8
STRENGTH PLANT FL (LBS)


5.0
4.8
4.6
4.4
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4.0
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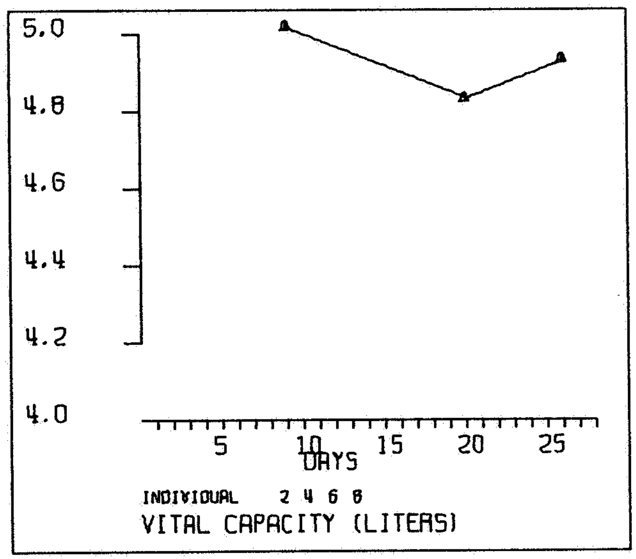
DAYS
INDIVIDUAL 1 3 5 7
VITAL CAPACITY (LITERS)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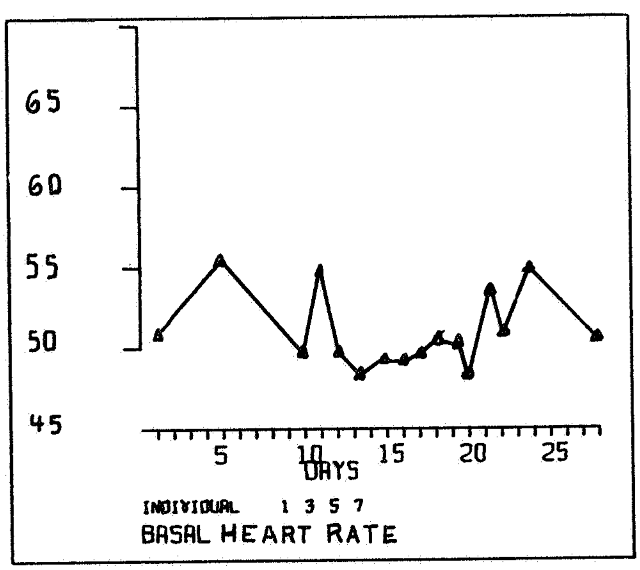
DAYS
INDIVIDUAL 2 4 6 8
VITAL CAPACITY (LITERS)


65
60
55
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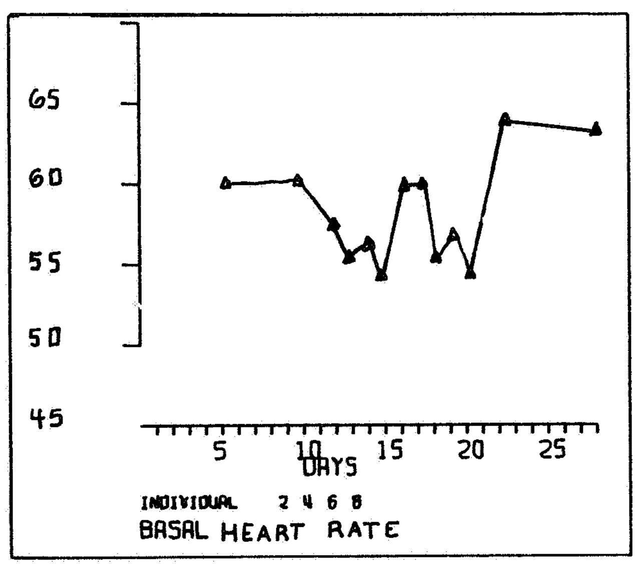
DAYS
INDIVIDUAL 1 3 5 7
BASAL HEART RATE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DAYS
INDIVIDUAL 2 4 6 8
BASAL HEART RATE

Appendix III: Computer Print-Out of Basic Data

The computer print-out of all individual values appears on the following pages. Means of each of the groups' values were calculated by computer and appear to the right of the individual values. The exercise subjects' data (individuals 1, 3, 5, and 7) appear on the left, and the control subjects' data (individuals 2, 4, 6, and 8) appear on the right. The order of each parameter is the same as the order of the graphs in Appendix II. The external controls' data (individuals 10 and 12) appear after the last parameter of the exercise and control groups. The data for external controls were not discussed, for reasons stated in Part III.

AVERAGES FOR FLUID INTAKE (LITERS)

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
1	1998.00	1758.00	1567.00	1567.00	1722.500	204.549
2	2095.00	2364.00	1900.00	2410.00	2192.250	239.291
3	2325.00	2560.00	1920.00	2963.00	2442.000	436.478
4	2778.00	2038.00	1890.00	2837.00	2385.750	491.320
5	2875.00	2144.00	2482.00	2900.00	2600.250	359.391
6	2825.00	1780.00	2303.00	2680.00	2397.000	466.475
7	2528.00	1898.00	2427.00	2850.00	2425.750	395.375
8	2625.00	1886.00	2802.00	2900.00	2553.250	459.160
9	2123.00	2180.00	2427.00	3080.00	2452.500	438.647
10	3926.00	3288.00	4052.00	4380.00	3911.500	457.601
11	2473.00	2508.00	2538.00	3040.00	2639.750	268.152
12	4227.00	4045.00	3554.00	3490.00	3829.000	363.137
13	2685.00	2580.00	2390.00	2570.00	2556.250	122.432
14	2773.00	2568.00	2540.00	3100.00	2745.250	258.304
15	3995.00	4105.00	3640.00	3515.00	3813.750	281.140
16	2800.00	2298.00	2628.00	2850.00	2644.000	249.495
17	2773.00	2470.00	2538.00	2820.00	2650.250	172.214
18	2912.00	2681.00	2354.00	2850.00	2699.250	250.013
19	4579.00	4184.00	3748.00	3580.00	4022.750	449.789
20	3130.00	3300.00	2675.00	3985.00	3272.500	543.361
21	4137.00	4090.00	4075.00	6095.00	4599.250	997.516
22	1870.00	3070.00	2025.00	2065.00	2257.500	548.156
23	1250.00	2645.00	3110.00	2070.00	2268.750	801.378
24	4165.00	1585.00	2620.00	1720.00	2522.500	1187.466
25	3575.00	1895.00	2305.00	3700.00	2868.750	904.759
26	2400.00	2530.00	1745.00	2820.00	2373.750	454.448

AVERAGES FOR FLUID INTAKE (LITERS)

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
1	2622.00	1842.00	1500.00	1765.00	1932.250	482.602
2	2183.00	1903.00	1780.00	2680.00	2136.500	399.654
3	2407.00	2127.00	1886.00	2655.00	2268.750	334.112
4	3432.00	2122.00	1520.00	2385.00	2364.750	798.324
5	3403.00	2183.00	2100.00	2418.00	2526.000	599.977
6	2627.00	1847.00	2126.00	2515.00	2278.750	359.088
7	2370.00	2372.00	1560.00	2385.00	2171.750	407.888
8	2433.00	2043.00	2030.00	2418.00	2231.000	224.735
9	2497.00	2197.00	1540.00	2915.00	2287.250	578.675
10	4650.00	3467.00	3390.00	4257.00	3941.000	613.953
11	2116.00	2116.00	1960.00	2411.00	2150.750	188.442
12	3356.00	3322.00	3489.00	4158.00	3581.250	391.194
13	2142.00	2142.00	1980.00	2283.00	2136.750	123.848
14	2116.00	2116.00	1960.00	2391.00	2145.750	179.277
15	3512.00	3648.00	3394.00	4165.00	3679.750	339.739
16	2142.00	2142.00	2260.00	2000.00	2136.000	106.370
17	2116.00	2116.00	2223.00	2331.00	2196.500	102.880
18	2252.00	1832.00	1937.00	2316.00	2084.250	236.051
19	3684.00	3917.00	3154.00	3883.00	3659.500	352.320
20	2605.00	2055.00	2990.00	2930.00	2645.000	428.155
21	3497.00	3470.00	3950.00	4785.00	3925.500	613.849
22	4129.00	2625.00	2915.00	3185.00	3213.500	651.764
23	3200.00	2190.00	3020.00	1955.00	2591.250	611.070
24	3040.00	1905.00	2485.00	2006.00	2359.000	519.731
25	3800.00	2125.00	2100.00	3035.00	2765.000	815.669
26	3660.00	1840.00	2575.00	3700.00	2943.750	901.696

AVERAGES FOR URINE VOLUME (LITERS)

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
1	1215.00	820.00	933.00	1328.00	1074.000	237.202
2	1440.00	960.00	1270.00	1085.00	1188.750	210.411
3	1510.00	1070.00	1220.00	1140.00	1235.000	193.305
4	1120.00	1200.00	1098.00	1307.00	1181.250	94.599
5	1210.00	1470.00	1076.00	1300.00	1264.000	165.320
6	1665.00	1180.00	1118.00	1120.00	1270.750	264.403
7	1625.00	950.00	1350.00	1310.00	1308.750	277.139
8	1445.00	1095.00	1209.00	900.00	1162.250	227.619
9	1460.00	1192.00	1387.00	1060.00	1274.750	182.467
10	1900.00	1803.00	1825.00	1952.00	1870.000	68.649
11	1410.00	1305.00	1204.00	1740.00	1414.750	232.573
12	1834.00	2351.00	2116.00	1700.00	2000.250	291.097
13	1572.00	1271.00	1265.00	1240.00	1337.000	157.241
14	1380.00	1077.00	1160.00	1325.00	1235.500	141.083
15	2222.00	2107.00	2200.00	1791.00	2080.000	199.009
16	1596.00	1301.00	1715.00	1600.00	1553.000	176.829
17	1380.00	1374.00	1251.00	1160.00	1291.250	105.784
18	1249.00	1367.00	1371.00	1180.00	1291.750	93.557
19	2522.00	2286.00	2871.00	2150.00	2457.250	315.759
20	1176.00	1014.00	878.00	1038.00	1026.500	122.053
21	2450.00	1650.00	2533.00	3520.00	2538.250	766.080
22	950.00	967.00	848.00	1135.00	975.000	118.909
23	695.00	790.00	825.00	1430.00	935.000	334.539
24	1130.00	795.00	830.00	880.00	908.750	151.568
25	1635.00	840.00	1615.00	780.00	1217.500	471.248
26	1110.00	613.00	2191.00	650.00	1141.000	735.601

AVERAGES FOR URINE VOLUME (LITERS)

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
1	569.00	1090.00	939.00	945.00	885.750	222.407
2	780.00	1100.00	871.00	1085.00	959.000	158.684
3	955.00	1350.00	950.00	1110.00	1091.250	187.811
4	720.00	1170.00	1034.00	1231.00	1038.750	227.897
5	760.00	1500.00	800.00	965.00	1006.250	340.915
6	1040.00	1450.00	887.00	1210.00	1146.750	241.403
7	1110.00	1250.00	760.00	1020.00	1035.000	206.317
8	1030.00	1310.00	931.00	1045.00	1079.000	162.093
9	1202.00	1378.00	825.00	1101.00	1126.500	231.304
10	2644.00	2334.00	1172.00	1532.00	1920.500	684.500
11	1258.00	1338.00	1387.00	1339.00	1330.500	53.470
12	2018.00	2984.00	1941.00	2240.00	2295.750	476.021
13	1078.00	1352.00	1350.00	1275.00	1263.750	128.914
14	947.00	1295.00	1308.00	1457.00	1251.750	216.051
15	1891.00	2433.00	1232.00	2477.00	2008.250	582.080
16	1189.00	1313.00	1166.00	1072.00	1185.000	99.214
17	1034.00	1222.00	1597.00	1227.00	1270.000	235.781
18	1066.00	1583.00	1292.00	1164.00	1276.250	224.461
19	2516.00	2360.00	2949.00	2329.00	2538.500	285.639
20	1340.00	880.00	1105.00	946.00	1067.750	204.598
21	1880.00	2417.00	1520.00	2916.00	2183.250	611.943
22	1395.00	1150.00	1393.00	582.00	1130.000	383.013
23	935.00	1300.00	1280.00	835.00	1087.500	237.504
24	900.00	1300.00	1122.00	940.00	1065.500	183.778
25	585.00	1720.00	1038.00	904.00	1061.750	478.202
26	600.00	1380.00	1235.00	897.00	1028.000	349.809

AVERAGES FOR DAY URINE FLOW ML/MN

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
1	0.83	0.54	0.64	1.30	0.827	0.337
2	1.15	0.75	0.91	0.94	0.938	0.164
3	1.22	0.81	0.82	1.06	0.977	0.199
4	0.79	0.81	0.81	1.09	0.875	0.144
5	1.06	1.25	0.77	0.89	0.992	0.209
6	1.26	1.19	0.86	0.95	1.065	0.191
7	1.14	0.70	1.14	1.15	1.032	0.222
8	1.29	1.08	0.78	0.54	0.922	0.330
9	1.10	0.92	1.08	0.82	0.980	0.134
10	-0.00	1.52	1.44	1.84	1.600	0.212
11	0.89	0.94	0.92	1.71	1.115	0.397
12	1.60	2.35	1.72	1.46	1.782	0.393
13	1.38	1.18	1.05	1.10	1.177	0.145
14	1.11	0.79	0.90	1.09	0.972	0.154
15	2.27	1.90	1.80	1.55	1.880	0.299
16	1.43	1.17	1.50	1.50	1.400	0.157
17	1.11	1.11	1.07	0.95	1.060	0.076
18	0.94	1.09	1.11	0.93	1.017	0.096
19	2.26	2.14	2.70	2.40	2.375	0.241
20	0.74	0.86	0.57	0.70	0.717	0.120
21	0.91	1.35	2.45	3.31	2.005	1.085
22	0.76	0.75	0.67	0.64	0.705	0.059
23	0.48	0.55	0.44	1.30	0.692	0.408
24	0.63	0.60	0.43	0.33	0.497	0.142
25	1.12	0.73	0.90	-0.00	0.917	0.196
26	0.70	0.46	1.69	0.47	0.830	0.584

AVERAGES FOR DAY URINE FLOW ML/MN

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
1	0.39	0.69	0.83	0.81	0.680	0.203
2	0.64	0.87	0.71	0.74	0.740	0.096
3	0.75	1.11	0.84	0.90	0.900	0.153
4	0.53	0.70	0.86	0.97	0.765	0.192
5	0.55	1.29	0.55	0.69	0.770	0.353
6	0.81	1.19	0.75	1.00	0.938	0.199
7	0.83	0.93	0.60	0.80	0.790	0.138
8	0.66	0.97	0.67	0.65	0.737	0.155
9	1.07	1.24	0.62	0.80	0.932	0.276
10	2.24	2.06	1.03	1.26	1.647	0.592
11	1.08	1.24	1.22	1.13	1.167	0.075
12	2.16	2.91	1.80	2.04	2.227	0.479
13	1.02	1.12	1.02	1.12	1.070	0.058
14	0.67	0.95	1.10	1.23	0.987	0.241
15	0.96	2.38	1.05	2.24	1.657	0.756
16	1.04	1.06	0.95	0.84	0.972	0.100
17	0.77	0.87	1.38	0.93	0.987	0.270
18	0.73	1.37	1.04	0.85	0.997	0.279
19	2.72	2.14	2.54	2.12	2.380	0.298
20	0.76	-0.00	0.87	0.82	0.817	0.055
21	1.66	1.38	1.33	2.85	1.805	0.712
22	0.56	0.95	0.98	0.33	0.705	0.315
23	0.58	0.95	1.14	0.76	0.857	0.241
24	0.64	-0.00	0.81	0.63	0.693	0.101
25	0.96	1.45	0.71	0.75	0.967	0.340
26	0.14	1.07	0.96	0.79	0.740	0.416

AVERAGES FOR NIGHT URINE FLO (ML/MN)

INDIVIDUAL / DAYS	1	3	5	7	MEAN	STD DEV
1	0.87	0.59	0.84	0.72	0.755	0.128
2	0.78	0.49	0.85	0.66	0.695	0.158
3	0.70	0.62	0.90	0.46	0.670	0.183
4	0.76	0.88	0.69	0.61	0.735	0.114
5	0.54	0.55	0.72	0.92	0.682	0.179
6	0.94	0.45	0.37	0.49	0.562	0.257
7	1.10	0.58	0.64	0.56	0.720	0.256
8	0.89	0.43	0.94	0.75	0.752	0.230
9	0.94	0.65	0.99	0.58	0.790	0.205
10	0.96	0.89	0.74	0.57	0.790	0.173
11	1.12	0.85	0.70	0.48	0.787	0.269
12	0.76	0.53	1.01	0.98	0.820	0.223
13	0.62	0.41	0.61	0.48	0.530	0.102
14	0.77	0.66	0.64	0.63	0.675	0.065
15	0.61	0.14	1.07	0.68	0.625	0.381
16	0.64	0.45	0.69	0.41	0.547	0.138
17	0.68	0.69	0.52	0.53	0.605	0.093
18	0.72	0.51	0.95	0.66	0.710	0.183
19	0.71	0.47	0.73	0.54	0.612	0.128
20	1.01	0.41	0.80	0.76	0.745	0.249
21	1.19	0.71	0.51	0.69	0.775	0.291
22	0.48	0.56	0.46	1.07	0.642	0.288
23	0.48	0.54	0.85	0.67	0.635	0.164
24	1.12	0.46	0.90	1.33	0.952	0.372
25	1.16	0.30	1.58	-0.00	1.013	0.652
26	0.93	0.35	1.23	0.43	0.735	0.418

AVERAGES FOR NIGHT URINE FLO (ML/MN)

INDIVIDUAL / DAYS	2	4	6	8	MEAN	STD DEV
1	0.41	0.55	0.36	0.45	0.442	0.081
2	0.45	0.56	0.36	0.76	0.532	0.172
3	0.51	0.61	0.39	0.48	0.497	0.091
4	0.45	1.03	0.49	0.70	0.667	0.265
5	0.49	0.56	0.58	0.63	0.565	0.058
6	0.56	0.66	0.41	0.52	0.537	0.103
7	0.68	0.73	0.42	0.52	0.587	0.143
8	0.82	0.82	0.62	0.83	0.772	0.102
9	0.67	0.50	0.44	0.71	0.580	0.130
10	1.00	0.83	0.56	0.74	0.782	0.183
11	0.44	0.63	0.40	0.77	0.560	0.172
12	0.68	0.59	0.47	0.62	0.590	0.088
13	0.42	0.70	0.49	0.50	0.527	0.120
14	0.65	0.83	0.64	0.62	0.685	0.097
15	0.84	0.80	0.56	0.73	0.732	0.124
16	0.59	0.66	0.60	0.54	0.597	0.049
17	0.63	0.82	0.63	0.70	0.695	0.090
18	0.71	0.61	0.55	0.74	0.652	0.088
19	0.85	0.60	1.14	0.62	0.802	0.252
20	1.24	-0.00	0.60	0.41	0.750	0.435
21	0.55	0.68	0.43	0.34	0.500	0.148
22	1.81	0.56	0.96	0.54	0.967	0.594
23	0.81	0.81	0.46	0.27	0.587	0.268
24	0.59	-0.00	0.72	0.33	0.547	0.199
25	0.60	0.72	0.76	0.38	0.615	0.171
26	0.81	0.82	0.73	0.37	0.682	0.212

AVERAGES FOR A.M. BODY WT. (KG)

INDIVIDUAL / DAYS	1	3	5	7	MEAN	STD DEV
1	81.90	63.09	66.85	69.38	70.305	8.151
2	81.56	63.00	66.44	67.82	69.705	8.159
3	80.79	62.02	66.49	67.34	69.160	8.097
4	80.76	63.02	65.53	67.11	69.105	7.950
5	80.75	63.14	64.74	67.59	69.055	8.011
6	80.65	63.07	65.21	67.89	69.205	7.881
7	81.04	62.89	65.09	67.22	69.060	8.180
8	81.11	63.19	65.70	66.99	69.247	8.064
9	81.70	62.88	66.98	67.40	69.740	8.230
10	80.99	63.01	67.22	67.71	69.732	7.796
11	81.25	62.78	66.71	67.92	69.665	8.029
12	80.69	61.77	66.10	67.70	69.065	8.145
13	81.85	62.38	67.03	68.17	69.857	8.378
14	80.09	62.28	66.99	67.62	69.245	7.613
15	80.84	62.71	67.19	67.86	69.650	7.802
16	80.65	63.14	67.63	68.36	69.945	7.501
17	80.17	62.81	67.32	67.72	69.505	7.450
18	80.11	62.88	67.35	67.85	69.547	7.388
19	80.33	62.75	67.76	68.31	69.787	7.460
20	80.34	62.26	67.29	67.93	69.455	7.687
21	81.54	63.48	67.97	68.33	70.330	7.792
22	81.26	63.92	68.51	68.05	70.435	7.506
23	81.00	64.04	68.70	68.48	70.555	7.287
24	80.52	63.86	68.01	68.07	70.115	7.211
25	81.52	63.66	69.02	67.05	70.313	7.793
26	81.47	63.79	68.93	67.76	70.488	7.645

AVERAGES FOR A.M. BODY WT. (KG)

INDIVIDUAL / DAYS	2	4	6	8	MEAN	STD DEV
1	70.30	69.57	60.23	80.06	70.040	8.102
2	68.91	69.20	59.49	79.29	69.222	8.086
3	68.66	69.00	59.69	78.90	69.062	7.848
4	68.91	69.41	59.59	78.94	69.212	7.902
5	68.62	69.80	58.65	78.67	68.935	8.193
6	68.19	69.98	58.82	79.04	69.007	8.288
7	68.69	69.06	59.06	79.07	68.970	8.171
8	69.37	69.87	59.24	79.28	69.440	8.186
9	69.35	69.75	59.59	79.53	69.555	8.142
10	69.30	68.88	59.91	79.95	69.510	8.197
11	68.83	69.30	59.15	79.91	69.297	8.482
12	68.83	69.75	58.94	79.53	69.262	8.414
13	68.43	69.41	59.04	80.08	69.240	8.607
14	68.13	69.37	58.34	79.96	68.950	8.844
15	68.52	69.46	57.87	79.90	68.937	9.002
16	68.99	69.56	58.77	80.12	69.360	8.720
17	68.55	69.47	58.98	80.01	69.252	8.598
18	68.83	69.44	58.50	80.13	69.225	8.835
19	68.87	68.63	58.67	80.05	69.055	8.736
20	68.88	69.29	58.12	79.85	69.035	8.873
21	68.65	70.09	58.39	79.55	69.170	8.662
22	69.51	69.64	58.49	79.43	69.267	8.556
23	69.72	70.13	58.78	81.00	69.907	9.073
24	69.63	70.16	58.41	80.57	69.692	9.052
25	69.32	70.32	58.62	80.90	69.790	9.105
26	68.77	69.86	58.84	80.53	69.500	8.869

AVERAGES FOR P.M. BODY WT. (KG)

INDIVIDUAL / DAYS	1	3	5	7	MEAN	STD DEV
4	81.38	64.12	64.89	68.39	69.695	8.009
9	81.55	63.29	67.87	68.30	70.252	7.866
10	82.20	63.78	67.46	68.66	70.525	8.055
11	81.16	63.69	67.48	68.43	70.190	7.595
12	81.75	62.65	68.10	69.03	70.382	8.084
13	80.84	62.63	67.67	68.57	69.927	7.730
14	81.59	63.22	67.89	68.70	70.350	7.873
15	81.31	64.10	68.64	69.06	70.777	7.372
16	80.83	63.30	68.07	68.33	70.132	7.497
17	80.74	63.75	68.03	68.52	70.260	7.308
18	81.24	63.10	68.55	69.20	70.522	7.651
19	81.69	63.30	68.03	68.45	70.367	7.901
20	82.09	64.02	68.81	69.23	71.037	7.738
22	81.70	64.80	69.36	69.52	71.345	7.242
26	82.00	63.43	69.11	68.65	70.797	7.900

AVERAGES FOR P.M. BODY WT. (KG)

INDIVIDUAL / DAYS	2	4	6	8	MEAN	STD DEV
4	69.04	70.76	59.18	79.43	69.602	8.304
9	70.38	70.34	-0.00	80.83	73.850	6.045
10	69.60	70.25	59.74	80.68	70.068	8.554
11	70.29	70.04	59.36	80.47	70.040	8.620
12	69.19	70.15	59.86	80.86	70.015	8.591
13	68.58	70.03	59.91	80.71	69.807	8.532
14	69.51	70.27	58.40	80.69	69.717	9.107
15	69.93	70.49	59.45	80.90	70.192	8.760
16	69.33	70.41	59.70	80.71	70.037	8.591
17	69.50	70.61	59.04	80.77	69.980	8.883
18	69.67	69.63	59.17	81.03	69.875	8.928
19	69.62	69.97	58.96	80.43	69.745	8.766
20	69.79	70.33	58.97	80.17	69.815	8.662
22	70.87	70.70	59.65	81.80	70.755	9.043
26	70.60	69.85	59.64	80.35	70.110	8.461

AVERAGES FOR 24 HR. EVAP LOSS (MLS)

INDIVIDUAL / DAYS	1	3	5	7	MEAN	STD DEV
1	1123.00	1028.00	1040.00	1800.00	1247.750	370.582
2	1425.00	2140.00	580.00	1805.00	1487.500	671.820
3	850.00	730.00	1660.00	2050.00	1322.500	637.044
4	1670.00	718.00	1580.00	1040.00	1252.000	451.814
5	1765.00	714.00	940.00	1310.00	1182.250	459.660
6	770.00	780.00	1310.00	2230.00	1272.500	686.361
7	830.00	948.00	470.00	1770.00	1004.500	549.340
8	590.00	800.00	363.00	1590.00	835.750	533.559
9	1720.00	980.00	1990.00	1710.00	1600.000	433.205
10	-0.00	1485.00	1660.00	2160.00	1768.333	350.297
11	1620.00	1720.00	1130.00	1520.00	1497.500	258.247
12	1490.00	1080.00	1140.00	1320.00	1257.500	185.540
13	1440.00	1220.00	1090.00	1880.00	1407.500	346.542
14	1440.00	1300.00	1180.00	1540.00	1365.000	157.797
15	1590.00	1568.00	1000.00	1220.00	1344.500	285.425
16	1680.00	1140.00	1220.00	1890.00	1482.500	361.144
17	1450.00	1024.00	1180.00	1430.00	1271.000	205.436
18	1340.00	1430.00	570.00	1210.00	1137.500	388.962
19	2050.00	1858.00	1350.00	1870.00	1782.000	301.091
20	754.00	1570.00	1070.00	2550.00	1486.000	784.863
21	1967.00	1990.00	1002.00	2850.00	1952.250	755.110
22	1180.00	1980.00	996.00	500.00	1164.000	615.151
23	1220.00	2030.00	2975.00	1050.00	1818.750	881.480
24	2035.00	990.00	780.00	2400.00	1551.250	788.293
25	1990.00	925.00	780.00	1700.00	1348.750	588.118
26	1630.00	2800.00	480.00	2060.00	1742.500	970.511

AVERAGES FOR 24 HR. EVAP LOSS (MLS)

INDIVIDUAL / DAYS	2	4	6	8	MEAN	STD DEV
1	3443.00	1122.00	1300.00	1590.00	1863.750	1070.355
2	1860.00	1003.00	710.00	1985.00	1389.500	629.045
3	1462.00	367.00	1040.00	1500.00	1092.250	526.527
4	3000.00	362.00	1430.00	1420.00	1553.000	1087.061
5	3070.00	680.00	1130.00	1020.00	1475.000	1080.447
6	1090.00	1130.00	1480.00	1810.00	1377.500	337.380
7	580.00	840.00	620.00	1490.00	882.500	420.823
8	1200.00	730.00	750.00	1350.00	1007.500	315.000
9	1245.00	360.00	1900.00	1620.00	1281.250	670.229
10	1350.00	710.00	1480.00	1650.00	1297.500	410.477
11	8600.00	8000.00	440.00	1450.00	4622.500	4273.409
12	15800.00	680.00	1420.00	1480.00	4845.000	7312.389
13	1360.00	830.00	1290.00	1130.00	1152.500	235.567
14	780.00	730.00	1120.00	990.00	905.000	182.300
15	910.00	1120.00	1260.00	1470.00	1190.000	235.655
16	1160.00	740.00	490.00	1040.00	857.500	302.035
17	800.00	760.00	1120.00	980.00	915.000	166.833
18	820.00	700.00	475.00	1070.00	766.250	247.904
19	1330.00	620.00	800.00	1310.00	1015.000	359.861
20	2130.00	375.00	1680.00	2280.00	1616.250	865.885
21	760.00	1500.00	2260.00	1990.00	1627.500	658.350
22	2940.00	690.00	1230.00	1030.00	1472.500	1003.407
23	2360.00	1160.00	2110.00	1550.00	1795.000	542.125
24	2450.00	445.00	1150.00	1100.00	1286.250	839.696
25	3770.00	850.00	840.00	2200.00	1915.000	1391.893
26	2050.00	1260.00	1350.00	3620.00	2070.000	1092.001

AVERAGES FOR NIGHT EVAP. LOSS (GM/HR)

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
4	22.70	32.60	42.00	45.30	35.650	10.173
9	72.50	36.90	39.00	28.90	44.325	19.281
10	64.80	65.50	44.60	45.60	55.125	11.587
11	28.40	56.90	50.30	43.70	44.825	12.204
12	17.30	30.00	60.50	65.50	43.325	23.392
13	48.20	34.40	44.50	81.00	52.025	20.178
14	40.00	38.60	38.00	55.00	42.900	8.110
15	29.20	27.80	47.70	45.00	37.425	10.380
16	32.20	21.10	42.20	47.00	35.625	11.479
17	34.20	31.80	45.60	53.00	41.150	9.932
18	71.20	23.80	49.60	57.00	50.400	19.870
19	65.50	47.50	42.50	36.40	47.975	12.534
20	42.70	26.00	65.50	51.70	46.475	16.560
22	29.40	36.90	42.10	35.60	36.000	5.220
26	42.70	43.80	52.00	70.00	52.125	12.618

AVERAGES FOR NIGHT EVAP. LOSS (GM/HR)

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
4	22.50	45.00	29.20	35.70	33.100	9.591
9	47.80	20.00	24.60	55.10	36.875	17.194
10	36.40	5.90	40.00	41.10	30.850	16.754
11	55.50	43.40	23.70	57.00	44.900	15.389
12	28.90	14.80	57.20	59.50	40.100	21.865
13	20.00	34.60	36.60	50.50	35.425	12.480
14	30.00	38.00	14.00	58.10	35.025	18.336
15	34.40	52.00	45.50	52.00	45.975	8.303
16	45.50	36.80	41.00	49.50	43.200	5.501
17	18.90	91.50	24.70	40.00	43.775	33.038
18	35.40	5.30	30.40	67.80	34.725	25.684
19	42.20	15.60	30.60	43.80	33.050	13.036
20	51.50	30.00	34.10	45.70	40.325	9.985
22	33.00	34.00	34.80	58.40	40.050	12.255
26	42.20	43.50	62.60	46.70	48.750	9.425

AVERAGES FOR DAY EVAP. LOSS (GM/HR)

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
4	99.00	28.20	40.00	42.00	52.300	31.723
9	71.50	45.00	40.00	96.50	63.250	26.123
10	85.00	59.00	82.50	15.50	60.500	32.205
20	68.00	90.00	40.00	80.00	69.500	21.626
22	60.00	90.00	40.60	18.70	52.325	30.257
26	75.00	53.00	1.00	94.00	55.750	40.161

AVERAGES FOR DAY EVAP. LOSS (GM/HR)

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
4	176.00	9.00	78.50	80.50	86.000	68.594
9	75.00	11.20	35.80	75.00	49.250	31.384
10	67.10	12.50	73.50	85.40	59.625	32.319
20	104.00	8.50	89.60	26.00	57.025	46.851
22	171.50	8.50	62.00	34.10	69.025	71.725
26	111.00	58.00	52.20	13.00	58.550	40.276

AVERAGES FOR ACT PERSP (GM/HR)

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
11	820.00	820.00	570.00	710.00	730.000	118.603
12	820.00	890.00	635.00	900.00	811.250	122.772
13	820.00	490.00	340.00	570.00	555.000	200.749
14	740.00	730.00	440.00	635.00	636.250	139.127
15	1160.00	710.00	630.00	780.00	820.000	234.805
16	800.00	590.00	490.00	600.00	620.000	129.872
17	820.00	640.00	520.00	650.00	657.500	123.390
18	620.00	650.00	390.00	612.00	568.000	119.789
19	780.00	670.00	590.00	796.00	709.000	97.112

AVERAGES FOR DAY IWL (GM/HR)

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
11	36.60	24.80	10.50	25.90	24.450	10.715
12	34.60	-0.00	-0.00	-0.00	34.600	0.000
13	13.60	28.00	23.60	40.00	26.300	10.942
14	23.20	17.00	26.00	23.20	22.350	3.803
15	10.90	40.60	-0.00	5.00	18.833	19.080
16	39.40	24.00	23.40	57.50	36.075	16.089
17	21.90	7.10	17.00	22.80	17.200	7.200
18	9.40	37.00	-0.00	6.40	17.600	16.868
19	46.50	50.50	25.80	49.00	42.950	11.552

AVERAGES FOR DAY IWL (GM/HR)

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
11	17.60	-0.00	15.60	62.90	32.033	26.750
12	73.50	37.20	60.20	62.90	58.450	15.285
13	78.10	34.60	63.50	44.80	55.250	19.372
14	34.00	25.60	70.00	32.40	40.500	20.001
15	40.00	43.90	57.40	66.00	51.825	12.037
16	50.00	27.20	7.50	40.00	31.175	18.335
17	42.00	1.90	58.60	40.30	35.700	23.998
18	33.60	0.70	14.30	30.70	19.825	15.322
19	63.20	31.60	34.80	60.00	47.400	16.501

AVERAGES FOR T20 BODY WATER (LITERS)

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
10	62.61	42.82	47.80	55.13	52.090	8.646
19	60.44	46.91	47.47	53.21	52.007	6.301

AVERAGES FOR T20 BODY WATER (LITERS)

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
10	53.07	46.52	46.65	62.79	52.257	7.658
19	47.73	48.70	45.94	55.71	49.520	4.282

AVERAGES FOR I131 BLD VOLUME (LITERS)

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
10	6.00	4.80	5.55	6.05	5.600	0.579
12	6.50	4.70	5.38	6.00	5.645	0.779
15	6.00	4.68	4.85	5.90	5.357	0.689
19	5.97	5.13	5.40	6.22	5.680	0.502
21	6.58	5.00	5.35	6.23	5.790	0.738
27	6.00	5.00	5.50	6.15	5.662	0.522

AVERAGES FOR I131 BLD VOLUME (LITERS)

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
10	5.40	6.00	4.90	6.20	5.625	0.591
12	5.35	5.80	4.35	6.03	5.382	0.744
15	5.00	5.75	4.65	5.65	5.262	0.527
19	4.70	5.92	4.68	6.48	5.445	0.901
21	5.38	5.40	5.18	6.13	5.522	0.417
27	5.35	5.50	4.93	6.00	5.445	0.442

AVERAGES FOR HEMATOCRIT (PERCENT)

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
10	42.30	46.30	49.10	46.40	46.025	2.802
12	45.60	48.40	49.80	49.80	48.400	1.980
15	47.00	45.90	47.20	47.90	47.000	0.829
19	45.30	45.70	46.60	46.50	46.025	0.629
21	43.60	43.30	45.60	44.60	44.275	1.044
27	45.40	46.00	45.70	41.60	44.675	2.065

AVERAGES FOR HEMATOCRIT (PERCENT)

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
10	44.90	49.10	48.30	44.40	46.675	2.370
12	50.00	47.70	48.50	52.30	49.625	2.022
15	52.30	49.80	49.80	50.60	50.625	1.179
19	48.70	48.00	49.20	50.10	49.000	0.883
21	49.50	45.80	46.90	46.50	47.175	1.615
27	44.10	48.00	47.60	47.10	46.700	1.772

AVERAGES FOR I131 PLASMA VOL. (L)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	3.73	2.74	3.02	3.45	3.235	0.441
12	3.75	2.59	2.90	3.13	3.092	0.491
15	3.44	2.69	2.73	3.28	3.035	0.381
19	3.46	2.95	3.07	3.54	3.255	0.289
21	3.92	3.01	3.09	3.65	3.417	0.440
27	3.54	2.88	3.17	3.78	3.342	0.398

AVERAGES FOR I131 PLASMA VOL. (L)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	3.15	3.30	2.71	3.65	3.202	0.389
12	2.87	3.24	2.39	3.11	2.903	0.374
15	2.60	3.10	2.53	3.13	2.840	0.319
19	2.58	3.29	2.55	3.47	2.972	0.476
21	2.91	3.11	2.93	3.49	3.110	0.269
27	3.17	3.04	2.75	3.38	3.085	0.264

AVERAGES FOR NA SERUM CONC. (MEQ/L)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	143.30	139.50	138.40	139.30	140.125	2.170
5	142.30	143.30	141.10	139.20	141.475	1.763
10	134.10	136.10	140.30	135.40	136.475	2.681
12	137.10	145.00	140.00	136.00	139.525	4.021
15	149.00	135.60	132.50	137.60	138.675	7.196
19	135.90	133.60	133.00	136.10	134.650	1.580
21	140.70	136.60	135.70	126.60	134.900	5.946
23	132.80	135.10	138.50	127.60	133.500	4.577
27	131.50	139.90	129.00	128.70	132.275	5.236

AVERAGES FOR NA SERUM CONC. (MEQ/L)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	145.20	139.00	138.10	139.10	140.350	3.264
5	145.90	140.00	136.70	138.20	140.200	4.032
10	134.80	135.20	134.90	133.70	134.650	0.656
12	135.40	141.40	139.30	134.40	137.625	3.287
15	144.50	135.00	136.20	136.10	137.950	4.400
19	135.00	136.50	136.40	136.60	136.125	0.754
21	134.90	135.20	140.60	127.00	134.425	5.600
23	136.30	132.50	139.50	132.10	135.100	3.491
27	132.00	138.50	128.20	129.20	131.975	4.638

AVERAGES FOR K SERUM CONC. (MEQ/L)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	4.50	3.80	3.95	3.27	3.880	0.506
5	4.80	3.92	3.71	4.00	4.107	0.478
10	3.22	3.24	4.11	3.51	3.520	0.415
12	3.40	4.26	4.39	3.55	3.900	0.497
15	3.45	3.24	3.48	3.49	3.415	0.118
19	3.55	3.12	3.52	3.64	3.457	0.231
21	4.11	3.40	3.80	3.82	3.782	0.292
23	3.13	3.51	4.61	3.81	3.765	0.628
27	3.71	3.44	4.21	3.40	3.690	0.373

AVERAGES FOR K SERUM CONC. (MEQ/L)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	4.88	3.55	4.00	3.15	3.895	0.743
5	4.23	3.86	4.25	3.97	4.077	0.193
10	3.45	3.68	4.02	3.26	3.602	0.327
12	3.90	3.61	3.94	3.14	3.647	0.369
15	4.70	3.51	3.75	3.22	3.795	0.641
19	4.42	3.06	3.74	3.69	3.727	0.556
21	4.28	3.52	4.11	3.44	3.837	0.420
23	4.31	3.48	4.76	4.12	4.167	0.531
27	4.29	3.49	4.21	3.90	3.972	0.363

AVERAGES FOR CL SERUM CONC. (MEQ/L)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	106.50	103.50	99.50	102.50	103.000	2.887
5	107.50	111.00	101.00	102.50	105.500	4.601
10	98.50	100.50	105.50	104.00	102.125	3.198
12	98.00	97.50	98.00	99.00	98.125	0.629
15	100.00	99.50	98.50	100.00	99.500	0.707
19	99.00	100.00	95.50	101.00	98.875	2.394
21	98.50	99.50	103.00	102.50	100.875	2.213
23	96.00	97.00	105.50	104.00	100.625	4.820
27	96.00	100.50	98.50	101.00	99.000	2.273

AVERAGES FOR CL SERUM CONC. (MEQ/L)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	108.50	103.50	102.50	99.00	103.375	3.924
5	107.50	104.00	95.50	105.50	103.125	5.282
10	100.50	96.00	99.50	103.00	99.750	2.901
12	97.00	98.00	98.00	98.50	97.875	0.629
15	97.50	98.50	97.50	98.50	98.000	0.577
19	97.00	98.50	96.00	100.50	98.000	1.958
21	97.50	95.50	99.00	101.00	98.250	2.327
23	97.70	97.00	104.50	102.00	100.300	3.567
27	98.00	98.00	96.00	100.00	98.000	1.633

AVERAGES FOR OSMOLARITY SERUM (OSM/L)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	284.00	289.00	286.00	286.30	286.325	2.055
5	309.40	301.00	307.10	290.20	301.925	8.583
10	281.40	288.00	289.10	282.70	285.300	3.817
12	288.80	289.20	275.20	274.50	281.925	8.176
15	284.60	287.30	272.90	278.30	280.775	6.464
19	288.10	288.90	281.30	286.40	286.175	3.413
21	287.30	270.10	278.10	277.10	278.150	7.062
23	275.60	285.50	285.40	280.30	281.700	4.736
27	266.10	276.20	278.00	276.30	274.150	5.430

AVERAGES FOR OSMOLARITY SERUM (OSM/L)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	291.00	293.00	286.90	285.00	288.975	3.670
5	304.70	293.50	298.30	289.60	296.525	6.509
10	280.50	284.00	281.60	286.90	283.250	2.838
12	286.90	280.10	278.20	275.10	280.075	4.995
15	292.80	282.40	290.20	280.10	286.375	6.085
19	288.20	288.90	285.10	277.20	284.850	5.361
21	287.20	269.50	281.30	278.60	279.150	7.368
23	282.50	276.90	288.60	281.30	282.325	4.827
27	268.10	268.90	283.70	278.40	274.775	7.569

AVERAGES FOR OSMOL POST EX SERUM

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	278.00	282.80	275.70	243.50	270.000	17.913
12	276.80	285.70	271.70	272.50	276.675	6.420
15	276.10	280.90	272.60	279.70	277.325	3.753
19	274.60	290.90	280.60	282.70	282.200	6.739
21	279.40	271.00	282.40	279.20	278.000	4.891
27	265.70	274.70	280.80	276.40	274.400	6.344

AVERAGES FOR OSMOL POST EX SERUM

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	277.10	277.90	279.80	287.80	280.650	4.899
12	280.50	275.40	270.00	272.80	274.675	4.466
15	282.20	281.70	272.60	276.60	278.275	4.551
19	274.70	282.80	277.10	279.70	278.575	3.479
21	276.70	269.90	286.70	276.90	277.550	6.914
27	266.40	270.40	234.80	275.00	261.650	18.242

AVERAGES FOR CREATNINE SERUM (GM PCT)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	0.99	1.05	1.18	1.44	1.165	0.200
12	1.05	1.05	1.10	1.06	1.065	0.024
15	1.17	0.87	1.02	1.15	1.052	0.139
19	1.17	1.09	1.13	1.19	1.145	0.044
21	1.08	0.94	1.02	1.32	1.090	0.164
27	1.00	1.21	1.06	1.21	1.120	0.107

AVERAGES FOR CREATNINE SERUM (GM PCT)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	1.10	1.00	0.98	1.15	1.057	0.081
12	1.10	1.08	1.09	1.86	1.282	0.385
15	1.10	1.05	1.09	1.50	1.185	0.211
19	1.10	0.98	0.94	1.17	1.047	0.106
21	1.10	0.98	0.90	1.11	1.022	0.101
27	1.10	0.89	0.93	1.25	1.042	0.166

AVERAGES FOR REN PLAS FLOW PRE EX

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	904.00	462.00	770.00	768.00	726.000	187.154
12	635.00	500.00	804.00	887.00	706.500	173.052
15	814.00	402.00	678.00	778.00	668.000	186.433
19	680.00	588.00	694.00	881.00	710.750	122.853
21	606.00	574.00	1392.00	1218.00	947.500	419.076
27	899.00	448.00	739.00	990.00	769.000	237.825

AVERAGES FOR REN PLAS FLOW PRE EX

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	506.00	553.00	593.00	691.00	585.750	78.661
12	521.00	592.00	586.00	719.00	604.500	82.827
15	554.00	540.00	578.00	827.00	624.750	135.743
19	676.00	783.00	671.00	1078.00	802.000	191.114
21	850.00	846.00	713.00	977.00	846.500	107.804
27	610.00	690.00	673.00	756.00	682.250	60.013

AVERAGES FOR RPF EXERCISE (ML/MIN)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	770.00	329.00	434.00	490.00	505.750	188.383
12	507.00	343.00	459.00	475.00	446.000	71.508
15	625.00	316.00	390.00	497.00	457.000	134.405
19	815.00	437.00	465.00	616.00	583.250	173.352
21	656.00	361.00	495.00	574.00	521.500	125.577
27	645.00	341.00	594.00	527.00	526.750	132.927

AVERAGES FOR RPF EXERCISE (ML/MIN)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	373.00	236.00	475.00	783.00	466.750	232.463
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	526.00	470.00	469.00	766.00	556.250	142.647
27	464.00	468.00	510.00	608.00	512.500	66.980

AVERAGES FOR RPF POST EX (ML/MIN)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	639.00	357.00	669.00	585.00	562.500	141.340
12	526.00	492.00	534.00	604.00	539.000	47.004
15	576.00	500.00	850.00	645.00	642.750	150.323
19	688.00	503.00	850.00	663.00	676.000	142.031
21	907.00	507.00	846.00	692.00	738.000	178.608
27	901.00	389.00	656.00	637.00	645.750	209.169

AVERAGES FOR RPF POST EX (ML/MIN)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	373.00	265.00	562.00	593.00	448.250	156.135
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	593.00	782.00	599.00	694.00	667.000	89.543
27	530.00	714.00	613.00	627.00	621.000	75.344

AVERAGES FOR GFR INULIN PRE EXERCISE

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	196.00	121.00	132.00	88.00	134.250	45.213
12	193.00	106.00	173.00	119.00	147.750	41.852
15	133.00	117.00	95.00	100.00	111.250	17.289
19	170.00	101.00	114.00	107.00	123.000	31.780
21	179.00	106.00	138.00	163.00	146.500	31.838
27	151.00	86.00	116.00	137.00	122.500	28.267

AVERAGES FOR GFR INULIN PRE EXERCISE

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	84.00	68.00	138.00	227.00	129.250	71.719
12	94.00	119.00	71.00	142.00	106.500	30.730
15	165.00	98.00	131.00	149.00	135.750	28.745
19	122.00	113.00	144.00	187.00	141.500	33.010
21	145.00	99.00	141.00	155.00	135.000	24.712
27	122.00	99.00	132.00	117.00	117.500	13.820

AVERAGES FOR GFR INULIN EXERCISE

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	177.00	90.00	110.00	186.00	140.750	47.898
12	228.00	107.00	124.00	106.00	141.250	58.420
15	166.00	103.00	82.00	148.00	124.750	38.913
19	175.00	86.00	121.00	140.00	130.500	37.153
21	177.00	97.00	162.00	117.00	138.250	37.500
27	131.00	57.00	131.00	119.00	109.500	35.454

AVERAGES FOR GFR INULIN EXERCISE

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	54.00	28.00	133.00	140.00	88.750	56.222
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	116.00	96.00	116.00	143.00	117.750	19.294
27	135.00	87.00	123.00	124.00	117.250	20.887

AVERAGES FOR GFR INULIN POST EX

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	158.00	79.00	108.00	146.00	122.750	36.124
12	226.00	62.00	95.00	105.00	122.000	71.726
15	113.00	85.00	105.00	123.00	106.500	16.114
19	170.00	98.00	108.00	102.00	119.500	33.917
21	195.00	97.00	129.00	112.00	133.250	43.192
27	162.00	89.00	103.00	107.00	115.250	32.108

AVERAGES FOR GFR INULIN POST EX

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	31.00	146.00	122.00	129.00	107.000	51.659
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	131.00	88.00	124.00	114.00	114.250	18.839
27	99.00	120.00	127.00	116.00	115.500	11.902

AVERAGES FOR GFR ENDOG. CREAT. PRE EX

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	170.00	130.00	129.00	100.00	132.250	28.756
12	180.00	153.00	136.00	143.00	153.000	19.305
15	170.00	160.00	150.00	120.00	150.000	21.602
19	163.00	150.00	134.00	124.00	142.750	17.231
21	145.00	140.00	144.00	100.00	132.250	21.608
27	150.00	140.00	120.00	100.00	127.500	22.174

AVERAGES FOR GFR ENDOG. CREAT. PRE EX

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	100.00	140.00	130.00	155.00	131.250	23.229
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	115.00	108.00	140.00	150.00	128.250	19.973
27	100.00	140.00	110.00	120.00	117.500	17.078

AVERAGES FOR GFR ENDOG. CREAT. PO. EX

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	172.00	84.00	100.00	62.00	104.500	47.620
12	106.00	74.00	50.00	122.00	88.000	32.249
15	126.00	33.00	27.00	35.00	55.250	47.289
19	146.00	50.00	75.00	76.00	86.750	41.291
21	69.00	47.00	18.00	90.00	56.000	30.822
27	130.00	57.00	36.00	90.00	78.250	41.040

AVERAGES FOR GFR ENDOG. CREAT. PO. EX

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	115.00	119.00	100.00	100.00	108.500	9.950
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	119.00	159.00	91.00	85.00	113.500	33.759
27	100.00	158.00	90.00	100.00	112.000	31.027

AVERAGES FOR GFR ENDOG. CREAT. 24 HR.

INDIVIDUAL / DAYS	1	3	5	7	MEAN	STD DEV
1	198.00	125.00	129.00	95.00	136.750	43.561
5	150.00	142.00	129.00	98.00	129.750	22.867
9	198.00	123.00	129.00	102.00	138.000	41.641
11	180.00	153.00	147.00	142.00	155.500	16.941
12	180.00	160.00	136.00	143.00	154.750	19.619
13	180.00	150.00	139.00	124.00	148.250	23.698
14	179.00	171.00	140.00	120.00	152.500	27.429
16	170.00	152.00	129.00	119.00	142.500	22.956
18	163.00	152.00	134.00	124.00	143.250	17.538
20	143.00	140.00	144.00	101.00	132.000	20.736
23	151.00	134.00	108.00	99.00	123.000	23.847

AVERAGES FOR GFR ENDOG. CREAT. 24 HR.

INDIVIDUAL / DAYS	2	4	6	8	MEAN	STD DEV
1	95.00	167.00	130.00	149.00	135.250	30.794
5	92.00	149.00	130.00	154.00	131.250	28.135
9	118.00	124.00	130.00	171.00	135.750	24.005
11	115.00	124.00	109.00	143.00	122.750	14.841
12	120.00	130.00	120.00	156.00	131.500	17.000
13	125.00	140.00	143.00	136.00	136.000	7.874
14	138.00	157.00	133.00	136.00	141.000	10.863
16	137.00	153.00	107.00	140.00	134.250	19.449
18	127.00	150.00	139.00	165.00	145.250	16.174
20	115.00	108.00	142.00	153.00	129.500	21.455
23	102.00	143.00	114.00	122.00	120.250	17.251

AVERAGES FOR NA URINARY 24 HR (MEQ/L)

INDIVIDUAL / DAYS	1	3	5	7	MEAN	STD DEV
1	147.00	165.00	174.00	256.00	185.500	48.322
5	172.00	260.00	258.00	231.00	230.250	41.023
9	197.00	207.00	199.00	217.00	205.000	9.092
10	195.00	105.00	207.00	130.00	159.250	49.520
11	241.00	175.00	226.00	225.00	216.750	28.779
12	-0.00	-0.00	118.00	126.00	122.000	5.657
13	-0.00	-0.00	212.00	227.00	219.500	10.607
14	163.00	209.00	178.00	162.00	178.000	21.924
15	-0.00	-0.00	131.00	132.00	131.500	0.707
16	186.00	179.00	147.00	186.00	174.500	18.628
17	-0.00	-0.00	161.00	186.00	173.500	17.678
18	175.00	167.00	180.00	202.00	181.000	14.989
19	115.00	116.00	94.00	110.00	108.750	10.178
20	129.00	95.00	127.00	123.00	118.500	15.864
23	167.00	172.00	242.00	142.00	180.750	42.890
26	171.00	138.00	85.00	122.00	129.000	35.730

AVERAGES FOR NA URINARY 24 HR (MEQ/L)

INDIVIDUAL / DAYS	2	4	6	8	MEAN	STD DEV
1	237.00	217.00	204.00	255.00	228.250	22.411
5	251.00	256.00	163.00	254.00	231.000	45.380
9	253.00	203.00	183.00	238.00	219.250	31.983
10	42.00	106.00	178.00	178.00	126.000	65.483
11	256.00	197.00	239.00	227.00	229.750	24.865
12	-0.00	-0.00	99.00	108.00	103.500	6.364
13	-0.00	-0.00	130.00	174.00	152.000	31.113
14	195.00	185.00	153.00	163.00	174.000	19.356
15	-0.00	-0.00	144.00	93.00	118.500	36.062
16	221.00	167.00	147.00	185.00	180.000	31.432
17	-0.00	-0.00	141.00	154.00	147.500	9.192
18	159.00	133.00	168.00	212.00	168.000	32.873
19	88.00	87.00	49.00	90.00	78.500	19.706
20	172.00	88.00	70.00	124.00	113.500	45.000
23	246.00	126.00	124.00	242.00	184.500	68.729
26	172.00	55.00	25.00	132.00	96.000	67.809

AVERAGES FOR NA URINE OUTPT (MEQ/DAY)

INDIVIDUAL / DAYS	1	3	5	7	MEAN	STD DEV
1	147.08	147.95	159.27	280.68	183.747	64.859
5	252.39	382.94	276.33	300.26	302.981	56.776
9	276.33	245.87	363.36	230.64	279.047	59.331
10	280.68	178.85	378.59	254.13	273.064	82.519
11	339.43	228.46	271.98	391.64	307.876	72.130
12	-0.00	-0.00	250.22	215.40	232.811	24.616
13	-0.00	-0.00	269.80	280.68	275.239	7.693
14	226.28	226.28	206.70	215.40	218.668	9.484
15	-0.00	-0.00	289.38	237.16	263.272	36.925
16	298.09	232.81	252.39	298.09	270.344	33.016
17	-0.00	-0.00	202.35	215.40	208.877	9.231
18	219.76	228.46	245.87	237.16	232.811	11.236
19	289.38	265.01	274.15	239.34	266.971	20.986
20	152.31	96.61	112.27	171.45	133.159	34.668
23	112.27	136.21	201.04	202.35	162.968	45.779
26	191.47	84.42	187.12	178.42	160.357	50.914

AVERAGES FOR NA URINE OUTPT (MEQ/DAY)

INDIVIDUAL / DAYS	2	4	6	8	MEAN	STD DEV
1	134.[illegible]	237.16	191.47	276.33	209.965	60.884
5	254.57	385.12	131.42	245.87	254.243	103.737
9	285.03	280.68	213.23	261.10	260.009	32.878
10	117.93	249.35	203.22	282.42	213.229	71.354
11	322.02	263.27	322.02	304.61	302.981	27.715
12	-0.00	-0.00	191.47	241.51	216.493	35.386
13	-0.00	-0.00	174.06	221.93	197.998	33.848
14	184.94	239.34	200.17	238.47	215.731	27.472
15	-0.00	-0.00	176.24	230.64	203.438	38.463
16	224.11	219.76	171.89	198.00	203.438	23.934
17	-0.00	-0.00	-0.00	-0.00	0.000	0.000
18	169.71	211.05	217.58	245.87	211.053	31.430
19	115.32	206.27	144.47	208.88	168.734	46.411
20	104.44	77.46	77.02	117.06	93.995	20.021
23	230.64	120.97	139.25	202.35	173.303	51.732
26	103.13	75.28	78.33	117.93	93.668	20.424

AVERAGES FOR NA URINE RATE (UEQ/MIN)

INDIVIDUAL / DAYS	1	3	5	7	MEAN	STD DEV
1	114.50	93.00	111.00	195.00	128.375	45.404
5	175.00	266.00	192.00	208.00	210.250	39.534
9	195.00	171.00	253.00	160.00	194.750	41.492
10	195.00	124.00	263.00	176.00	189.500	57.460
11	236.00	159.00	188.00	272.00	213.750	50.162
12	-0.00	-0.00	173.00	149.00	161.000	16.971
13	-0.00	-0.00	187.00	194.00	190.500	4.950
14	156.00	156.00	144.00	150.00	151.500	5.745
15	-0.00	-0.00	201.00	165.00	183.000	25.456
16	207.00	162.00	176.00	206.00	187.750	22.396
17	-0.00	-0.00	140.00	150.00	145.000	7.071
18	154.00	158.00	171.00	165.00	162.000	7.528
19	201.00	184.00	185.00	166.00	184.000	14.306
20	106.00	67.00	78.00	89.00	85.000	16.633
23	78.00	94.50	139.00	141.00	113.125	31.766
26	132.00	58.50	130.00	89.00	102.375	35.330

AVERAGES FOR NA URINE RATE (UEQ/MIN)

INDIVIDUAL / DAYS	2	4	6	8	MEAN	STD DEV
1	94.00	164.00	133.00	193.00	146.000	42.450
5	179.00	267.00	91.00	170.00	176.750	71.992
9	198.00	195.00	147.00	182.00	180.500	23.388
10	82.00	173.00	141.00	196.00	148.000	49.444
11	213.00	183.00	224.00	212.00	208.000	17.531
12	-0.00	-0.00	133.00	166.00	149.500	23.335
13	-0.00	-0.00	121.00	154.00	137.500	23.335
14	133.00	161.00	139.00	165.00	149.500	15.864
15	-0.00	-0.00	122.00	160.00	141.000	26.870
16	159.00	139.00	119.00	138.00	138.750	16.338
17	-0.00	-0.00	156.00	131.00	143.500	17.678
18	118.00	144.00	151.00	171.00	146.000	21.894
19	72.00	143.00	100.00	145.00	115.000	35.393
20	60.00	54.00	53.50	81.50	62.250	13.169
23	160.00	114.00	96.50	141.00	127.875	28.173
26	71.50	52.00	53.00	82.00	64.625	14.648

AVERAGES FOR NA URINE RATE POST EX.

INDIVIDUAL / DAYS	1	3	5	7	MEAN	STD DEV
10	266.00	92.00	200.00	198.00	189.000	71.972
12	157.00	139.00	160.00	90.00	136.500	32.357
15	130.00	99.00	121.00	76.00	106.500	24.145
19	212.00	130.00	150.00	111.00	150.750	43.828
21	240.00	79.00	170.00	244.00	183.250	77.362
27	220.00	150.00	213.00	126.00	177.250	46.457

AVERAGES FOR NA URINE RATE POST EX.

INDIVIDUAL / DAYS	2	4	6	8	MEAN	STD DEV
10	260.00	171.00	120.00	284.00	208.750	76.574
12	150.00	125.00	123.00	242.00	160.000	56.030
15	137.00	150.00	123.00	294.00	176.000	79.436
19	236.00	150.00	123.00	243.00	188.000	60.548
21	144.00	90.00	70.00	90.00	98.500	31.765
27	300.00	150.00	204.00	116.00	192.500	80.306

AVERAGES FOR K URINARY 24 HR (MEQ/L)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	60.00	98.00	113.00	89.00	90.000	22.316
5	68.00	53.00	103.00	64.00	72.000	21.618
9	57.00	58.00	36.00	82.00	58.250	18.804
10	57.00	29.00	41.00	36.00	40.750	11.899
11	47.00	42.00	47.00	31.00	41.750	7.544
12	-0.00	-0.00	29.00	29.00	29.000	0.000
13	-0.00	-0.00	66.00	59.00	62.500	4.950
14	60.00	62.00	57.00	45.00	56.000	7.616
15	-0.00	-0.00	31.00	34.00	32.500	2.121
16	60.00	54.00	41.00	45.00	50.000	8.602
17	-0.00	-0.00	49.00	54.00	51.500	3.536
18	53.00	49.00	47.00	55.00	51.000	3.651
19	31.00	32.00	31.00	32.00	31.500	0.577
20	56.00	49.00	64.00	75.00	61.000	11.165
23	34.00	51.00	45.00	45.00	43.750	7.089
26	35.00	64.00	29.00	70.00	49.500	20.502

AVERAGES FOR K URINARY 24 HR (MEQ/L)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	69.00	103.00	45.00	108.00	81.250	29.736
5	52.00	63.00	70.00	81.00	66.500	12.179
9	51.00	49.00	26.00	78.00	51.000	21.276
10	13.00	41.00	29.00	37.00	30.000	12.383
11	34.00	47.00	28.00	29.00	34.500	8.737
12	-0.00	-0.00	17.00	16.00	16.500	0.707
13	-0.00	-0.00	36.00	35.00	35.500	0.707
14	85.00	56.00	40.00	36.00	54.250	22.247
15	-0.00	-0.00	31.00	17.00	24.000	9.899
16	62.00	40.00	37.00	59.00	49.500	12.819
17	-0.00	-0.00	32.00	38.00	35.000	4.243
18	57.00	45.00	34.00	51.00	46.750	9.811
19	20.00	21.00	26.00	20.00	21.750	2.872
20	58.00	52.00	38.00	58.00	51.500	9.434
23	70.00	51.00	48.00	79.00	62.000	14.944
26	100.00	35.00	38.00	51.00	56.000	30.144

AVERAGES FOR K URINE OUTPUT (MEQ/DAY)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	71.61	79.28	104.86	97.19	88.235	15.416
5	97.19	76.73	109.97	84.40	92.072	14.618
9	84.40	69.05	66.50	86.96	76.726	10.441
10	81.84	48.59	74.17	71.61	69.054	14.316
11	66.50	56.27	56,27	53.71	58.184	5.671
12	-0.00	-0.00	61.38	51.15	56.266	7.234
13	-0.00	-0.00	84.40	74.17	79.284	7.234
14	81.84	66.50	66.50	58.82	68.414	9.655
15	-0.00	-0.00	69.05	61.38	65.217	5.425
16	94.63	71.61	69.05	71.61	76.726	11.996
17	-0.00	-0.00	61.38	61.38	61.381	0.000
18	66.50	69.05	63.94	63.94	65.857	2.449
19	76.73	74.17	89.51	69.05	77.366	8.704
20	66.50	48.59	56.27	84.40	63.939	15.487
23	23.02	40.92	38.36	63.94	41.560	16.884
26	38.36	38.36	61.38	46.04	46.036	10.851

AVERAGES FOR K URINE OUTPUT (MEQ/DAY)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	38.36	112.53	40.92	117.65	77.366	43.622
5	53.71	94.63	48.59	79.28	69.054	21.701
9	61.38	66.50	33.25	86.96	62.020	22.137
10	35.81	97.19	33.25	58.82	56.266	29.606
11	46.04	61.38	38.36	38.36	46.036	10.851
12	-0.00	-0.00	33.25	35.81	34.527	1.808
13	-0.00	-0.00	48.59	43.48	46.036	3.617
14	81.84	74.17	58.82	51.15	66.496	14.008
15	-0.00	-0.00	38.36	38.36	38.363	0.000
16	79.28	53.71	43.48	63.94	60.102	15.274
17	-0.00	-0.00	51.15	46.04	48.593	3.617
18	61.38	71.61	43.48	58.82	58.824	11.627
19	30.69	48.59	53.71	48.59	45.396	10.096
20	84.40	46.04	40.92	53.71	56.266	19.478
23	66.50	66.50	53.71	66.50	63.299	6.394
26	61.38	48.59	46.04	46.04	50.512	7.346

AVERAGES FOR K URINE RATE (UEQ/MIN)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	50.50	55.50	73.00	67.00	61.500	10.320
5	68.00	54.00	76.50	58.00	64.125	10.136
9	58.00	48.50	46.00	60.00	53.125	6.909
10	57.00	34.00	52.00	49.00	48.000	9.899
11	46.00	38.20	39.20	37.50	40.225	3.913
12	-0.00	-0.00	42.50	34.80	38.650	5.445
13	-0.00	-0.00	58.50	50.50	54.500	5.657
14	57.00	46.00	46.50	41.50	47.750	6.564
15	-0.00	-0.00	47.50	42.00	44.750	3.889
16	66.50	49.00	48.50	50.00	53.500	8.689
17	-0.00	-0.00	42.50	43.50	43.000	0.707
18	46.00	46.50	45.00	45.00	45.625	0.750
19	54.00	51.00	62.00	48.00	53.750	6.021
20	46.00	34.10	39.00	54.00	43.275	8.658
23	16.40	27.80	26.00	44.50	28.675	11.677
26	27.00	27.40	43.50	31.30	32.300	7.714

AVERAGES FOR K URINE RATE (UEQ/MIN)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	19.50	78.00	29.20	80.50	51.800	31.959
5	37.60	66.00	33.00	54.00	47.650	15.195
9	42.50	47.00	22.20	59.50	42.800	15.502
10	25.00	67.00	23.00	41.00	39.000	20.331
11	28.00	43.00	27.20	27.00	31.300	7.812
12	-0.00	-0.00	22.40	24.80	23.600	1.697
13	-0.00	-0.00	33.00	31.00	32.000	1.414
14	51.00	49.00	40.50	36.50	44.250	6.886
15	-0.00	-0.00	26.80	26.40	26.600	0.283
16	45.00	33.40	29.80	44.00	38.050	7.602
17	-0.00	-0.00	35.40	32.70	34.050	1.909
18	42.00	49.00	30.60	41.00	40.650	7.587
19	21.00	34.00	53.00	33.00	35.250	13.226
20	55.50	31.60	29.20	37.90	38.550	11.881
23	45.50	46.00	37.20	45.50	43.550	4.240
26	50.00	33.70	32.60	32.00	37.075	8.645

AVERAGES FOR K URINE RATE POST EX

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	113.00	51.00	60.00	125.00	87.250	37.170
12	111.00	76.00	60.00	78.00	81.250	21.407
15	117.00	85.00	88.00	80.00	92.500	16.663
19	122.00	100.00	101.00	106.00	107.250	10.178
21	117.00	40.00	85.00	137.00	94.750	42.319
27	132.00	40.00	133.00	77.00	95.500	45.317

AVERAGES FOR K URINE RATE POST EX

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	87.00	75.00	45.00	85.00	73.000	19.391
12	60.00	34.00	40.00	41.00	43.750	11.266
15	60.00	40.00	28.00	64.00	48.000	16.971
19	85.00	45.00	85.00	68.00	70.750	18.945
21	94.00	30.00	46.00	102.00	68.000	35.402
27	154.00	30.00	114.00	110.00	102.000	51.949

AVERAGES FOR CL URINARY 24 HR (MEQ/L)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	156.00	108.00	174.00	276.00	178.500	70.718
5	280.00	401.00	269.00	293.00	310.750	60.961
9	289.00	257.00	347.00	231.00	281.000	49.987
11	318.00	206.00	257.00	346.00	281.750	62.697
12	-0.00	-0.00	256.00	207.00	231.500	34.648
13	-0.00	-0.00	287.00	412.00	349.500	88.388
14	210.00	212.00	202.00	223.00	211.750	8.655
15	-0.00	-0.00	283.00	223.00	253.000	42.426
16	270.00	235.00	251.00	286.00	260.500	22.219
17	-0.00	-0.00	203.00	215.00	209.000	8.485
18	223.00	230.00	266.00	228.00	236.750	19.721
19	-0.00	-0.00	267.00	223.00	245.000	31.113
20	387.00	119.00	98.00	136.00	185.000	135.561
23	149.00	112.00	180.00	203.00	161.000	39.455
26	349.00	79.00	197.00	68.00	173.250	130.911

AVERAGES FOR CL URINARY 24 HR (MEQ/L)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	120.00	216.00	174.00	272.00	195.500	64.382
5	262.00	393.00	123.00	244.00	255.500	110.509
9	272.00	278.00	179.00	241.00	242.500	45.332
11	281.00	263.00	273.00	272.00	272.250	7.365
12	-0.00	-0.00	172.00	204.00	188.000	22.627
13	-0.00	-0.00	173.00	208.00	190.500	24.749
14	177.00	235.00	202.00	229.00	210.750	26.688
15	-0.00	-0.00	162.00	202.00	182.000	28.284
16	216.00	194.00	167.00	184.00	190.250	20.467
17	-0.00	-0.00	204.00	165.00	184.500	27.577
18	173.00	189.00	211.00	240.00	203.250	29.033
19	-0.00	-0.00	155.00	171.00	163.000	11.314
20	137.00	71.00	77.00	115.00	100.000	31.432
23	212.00	160.00	126.00	73.00	142.750	58.420
26	94.00	99.00	130.00	93.00	104.000	17.531

AVERAGES FOR CL URINE OUTPT (MEQ/DAY

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	156.53	108.30	174.30	276.39	178.879	70.736
5	282.03	400.49	269.34	293.31	311.293	60.263
9	290.49	258.06	346.90	231.27	281.679	49.768
11	318.70	200.81	257.21	366.01	285.680	72.473
12	-0.00	-0.00	256.65	201.09	228.869	39.287
13	-0.00	-0.00	290.49	414.59	352.540	87.748
14	202.22	202.78	200.52	222.81	207.082	10.526
15	-0.00	-0.00	283.44	222.81	253.123	42.877
16	269.90	235.21	251.01	284.85	260.245	21.685
17	-0.00	-0.00	203.06	214.91	208.986	8.376
18	222.81	229.86	266.24	228.45	236.836	19.837
19	-0.00	-0.00	266.80	224.50	245.650	29.914
20	389.20	119.30	98.71	136.22	185.859	136.428
23	149.48	111.40	180.50	201.09	160.617	39.070
26	349.72	78.40	198.27	68.25	173.661	131.386

AVERAGES FOR CL URINE OUTPT (MEQ/DAY

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	120.15	216.32	174.30	273.57	196.083	64.949
5	262.29	394.84	123.25	244.24	256.155	111.174
9	272.16	278.37	179.09	241.14	242.688	45.419
11	280.90	263.42	273.57	272.16	272.513	7.173
12	-0.00	-0.00	172.04	200.81	186.423	20.342
13	-0.00	-0.00	173.17	208.14	190.653	24.729
14	176.83	235.50	201.09	229.29	210.678	27.079
15	-0.00	-0.00	162.17	200.24	181.205	26.923
16	201.09	191.78	166.96	183.32	185.788	14.497
17	-0.00	-0.00	200.81	221.39	211.101	14.558
18	173.45	188.96	201.37	240.01	200.948	28.436
19	-0.00	-0.00	155.12	170.63	162.873	10.968
20	136.79	71.07	77.28	115.07	100.051	31.270
23	201.09	160.48	126.91	73.33	140.452	54.057
26	94.20	98.99	130.30	93.07	104.140	17.627

AVERAGES FOR CL URINE RATE (UEQ/MIN)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	108.00	75.00	121.00	192.00	124.000	49.295
5	194.00	278.00	187.00	203.00	215.500	42.178
9	201.00	178.00	241.00	160.00	195.000	34.957
11	221.00	143.00	178.00	240.00	195.500	43.562
12	-0.00	-0.00	178.00	144.00	161.000	24.042
13	-0.00	-0.00	199.00	286.00	242.500	61.518
14	146.00	147.00	140.00	155.00	147.000	6.164
15	-0.00	-0.00	197.00	155.00	176.000	29.698
16	188.00	163.00	174.00	199.00	181.000	15.769
17	-0.00	-0.00	141.00	149.00	145.000	5.657
18	155.00	160.00	185.00	158.00	164.500	13.820
19	-0.00	-0.00	185.00	155.00	170.000	21.213
20	269.00	83.00	68.00	94.00	128.500	94.271
23	103.00	78.00	125.00	141.00	111.750	27.366
26	242.00	55.00	137.00	47.00	120.250	90.787

AVERAGES FOR CL URINE RATE (UEQ/MIN)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	83.00	150.00	121.00	189.00	135.750	44.866
5	182.00	273.00	85.00	169.00	177.250	76.960
9	189.00	193.00	124.00	167.00	168.250	31.637
11	195.00	171.00	190.00	189.00	186.250	10.500
12	-0.00	-0.00	119.00	142.00	130.500	16.263
13	-0.00	-0.00	120.00	144.00	132.000	16.971
14	123.00	153.00	140.00	159.00	143.750	15.945
15	-0.00	-0.00	113.00	140.00	126.500	19.092
16	150.00	134.00	116.00	128.00	132.000	14.142
17	-0.00	-0.00	142.00	115.00	128.500	19.092
18	119.00	126.00	147.00	167.00	139.750	21.716
19	-0.00	-0.00	108.00	119.00	113.500	7.778
20	95.00	49.00	53.00	80.00	69.250	22.006
23	147.00	111.00	88.00	51.00	99.250	40.302
26	65.00	69.00	90.00	65.00	72.250	11.983

AVERAGES FOR CL URINE RATE POST EX

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	252.00	72.00	150.00	261.00	183.750	89.912
12	139.00	128.00	140.00	110.00	129.250	13.937
15	121.00	85.00	155.00	90.00	112.750	32.356
19	181.00	70.00	132.00	119.00	125.500	45.625
21	134.00	19.00	127.00	193.00	118.250	72.486
27	169.00	9.00	219.00	86.00	120.750	92.514

AVERAGES FOR CL URINE RATE POST EX

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	224.00	158.00	90.00	253.00	181.250	72.670
12	150.00	350.00	80.00	218.00	199.500	115.070
15	124.00	272.00	109.00	258.00	190.750	86.145
19	183.00	280.00	110.00	54.00	156.750	97.678
21	114.00	33.00	38.00	126.00	77.750	49.074
27	297.00	150.00	205.00	158.00	202.500	67.510

AVERAGES FOR OSMOL URINE 24 HR (MO/L)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	958.00	1127.00	1179.00	1182.00	1111.500	105.402
5	1025.00	1106.00	1371.00	1256.00	1189.500	154.269
9	1097.00	995.00	933.00	1315.00	1085.000	167.579
11	1040.00	925.00	1174.00	817.00	989.000	153.304
12	-0.00	-0.00	662.00	683.00	672.500	14.849
13	-0.00	-0.00	1006.00	1198.00	1102.000	135.765
14	989.00	1110.00	998.00	1198.00	1073.750	99.453
16	952.00	930.00	710.00	882.00	868.500	109.634
18	1027.00	831.00	935.00	1258.00	1012.750	182.052
20	1023.00	776.00	1100.00	1100.00	999.750	153.520
23	906.00	942.00	1329.00	865.00	1010.500	214.651
26	741.00	780.00	-0.00	-0.00	760.500	27.577

AVERAGES FOR OSMOL URINE 24 HR (MO/L)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	1169.00	1275.00	878.00	1284.00	1151.500	189.664
5	1269.00	1143.00	1116.00	1364.00	1223.000	115.248
9	1082.00	869.00	878.00	1500.00	1082.000	150.000
11	1025.00	862.00	849.00	946.00	920.500	81.864
12	-0.00	-0.00	492.00	520.00	506.000	19.799
13	-0.00	-0.00	710.00	855.00	782.500	102.530
14	1327.00	1100.00	784.00	855.00	1016.500	247.333
16	1157.00	894.00	801.00	1140.00	998.000	178.017
18	1132.00	663.00	717.00	1289.00	950.250	308.060
20	780.00	594.00	897.00	1100.00	842.750	212.081
23	1100.00	646.00	792.00	1129.00	916.750	236.290
26	1100.00	415.00	-0.00	-0.00	757.500	484.368

AVERAGES FOR OSMOL URINE POST EX

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	677.00	555.00	-0.00	147.00	459.667	277.563
12	249.00	481.00	-0.00	124.00	284.667	181.153
15	256.00	182.00	264.00	-0.00	234.000	45.211
19	136.00	-0.00	-0.00	-0.00	136.000	0.000
21	118.00	47.00	-0.00	-0.00	82.500	50.205
27	31.00	71.00	-0.00	-0.00	51.000	28.284

AVERAGES FOR OSMOL URINE POST EX

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	81.00	307.00	-0.00	684.00	357.333	304.635
12	-0.00	220.00	-0.00	272.00	246.000	36.770
15	291.00	157.00	966.00	-0.00	471.333	433.602
19	107.00	-0.00	-0.00	-0.00	107.000	0.000
21	106.00	41.00	-0.00	-0.00	73.500	45.962
27	102.00	-0.00	-0.00	-0.00	102.000	0.000

AVERAGES FOR CREATNINE UR. 24HR (MG()

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	196.00	231.00	204.00	183.00	203.500	20.273
5	196.00	146.00	204.00	157.00	175.750	28.547
9	196.00	156.00	204.00	199.00	188.750	22.081
11	208.00	177.00	102.00	124.00	152.750	48.452
12	-0.00	-0.00	158.00	129.00	143.500	20.506
13	-0.00	-0.00	175.00	154.00	164.500	14.849
14	219.00	198.00	117.00	150.00	171.000	46.152
16	219.00	147.00	111.00	123.00	150.000	48.374
18	219.00	147.00	159.00	180.00	176.250	31.595
20	162.00	300.00	240.00	186.00	222.000	61.384
23	186.00	229.00	102.00	132.00	162.250	56.465

AVERAGES FOR CREATNINE UR. 24HR (MG()

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	264.00	220.00	228.00	229.00	235.250	19.585
5	264.00	220.00	228.00	264.00	244.000	23.324
9	264.00	129.00	228.00	258.00	219.750	62.516
11	245.00	144.00	88.00	185.00	165.500	66.255
12	-0.00	-0.00	139.00	120.00	129.500	13.435
13	-0.00	-0.00	171.00	183.00	177.000	8.485
14	231.00	183.00	169.00	162.00	186.250	31.085
16	210.00	177.00	145.00	222.00	188.500	34.684
18	189.00	177.00	144.00	239.00	187.250	39.399
20	195.00	174.00	174.00	258.00	200.250	39.752
23	268.00	156.00	147.00	234.00	201.250	59.214

AVERAGES FOR CREATNINE UR. 24HR (GMS)

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
1	2.83	1.89	2.20	1.99	2.227	0.422
5	2.83	2.15	2.20	2.04	2.305	0.356
9	2.83	1.86	2.20	2.11	2.250	0.413
11	2.85	2.31	2.16	2.16	2.370	0.328
12	-0.00	-0.00	2.00	2.19	2.095	0.134
13	-0.00	-0.00	2.03	1.91	1.970	0.085
14	2.88	2.13	2.57	1.99	2.392	0.408
16	2.88	1.91	1.90	1.97	2.165	0.478
18	2.74	1.91	2.18	2.12	2.237	0.354
20	1.13	3.04	2.11	1.93	2.052	0.784
23	2.06	1.81	1.65	1.89	1.852	0.171

AVERAGES FOR CREATNINE UR. 24HR (GMS)

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
1	2.16	2.40	1.82	2.48	2.215	0.296
5	2.16	2.40	1.82	2.55	2.232	0.318
9	2.16	1.50	1.82	2.84	2.080	0.574
11	2.17	1.93	1.72	2.48	2.075	0.327
12	-0.00	-0.00	1.88	2.69	2.285	0.573
13	-0.00	-0.00	2.24	2.33	2.285	0.064
14	2.19	2.37	2.08	2.36	2.250	0.140
16	2.17	2.32	1.69	2.38	2.140	0.313
18	2.02	2.32	1.86	2.78	2.245	0.404
20	1.82	1.53	1.92	2.44	1.927	0.380
23	1.61	2.03	1.53	1.95	1.780	0.247

AVERAGES FOR NA/K SERUM

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
10	41.65	42.01	34.14	38.58	39.091	3.644
12	40.32	34.04	31.89	38.31	36.140	3.860
15	43.19	41.85	38.07	39.43	40.635	2.310
19	38.28	42.82	37.78	37.39	39.069	2.527
21	34.23	40.18	35.71	33.14	35.815	3.092
27	35.44	40.67	30.64	37.85	36.152	4.249

AVERAGES FOR NA/K SERUM

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
10	39.07	36.74	33.56	41.01	37.595	3.209
12	34.72	39.17	35.36	42.80	38.011	3.750
15	30.74	38.46	36.32	42.27	36.948	4.812
19	30.54	44.61	36.47	37.02	37.160	5.766
21	31.52	38.41	34.21	36.92	35.264	3.042
27	30.77	39.68	30.45	33.13	33.508	4.287

AVERAGES FOR NA/K URINE

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
1	2.05	1.87	1.52	2.89	2.082	0.581
5	2.60	4.99	2.51	3.56	3.415	1.153
9	3.27	3.56	5.46	2.65	3.738	1.212
10	3.43	3.68	5.10	3.55	3.941	0.782
11	5.10	4.06	4.83	7.29	5.323	1.385
12	0.00	0.00	4.08	4.21	4.144	0.095
13	0.00	0.00	3.20	3.78	3.491	0.416
14	2.76	3.40	3.11	3.66	3.235	0.386
15	0.00	0.00	4.19	3.86	4.027	0.231
16	3.15	3.25	3.66	4.16	3.555	0.460
17	0.00	0.00	3.30	3.51	3.403	0.150
18	3.30	3.31	3.85	3.71	3.542	0.277
19	3.77	3.57	3.06	3.47	3.468	0.299
20	2.29	1.99	2.00	2.03	2.076	0.144
23	4.88	3.33	5.24	3.16	4.153	1.059
26	4.99	2.20	3.05	3.88	3.529	1.191

AVERAGES FOR NA/K URINE

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
1	3.52	2.11	4.68	2.35	3.163	1.183
5	4.74	4.07	2.70	3.10	3.654	0.924
9	4.64	4.22	6.41	3.00	4.570	1.412
10	3.29	2.57	6.11	4.80	4.193	1.582
11	6.99	4.29	8.39	7.94	6.905	1.838
12	0.00	0.00	5.76	6.75	6.252	0.697
13	0.00	0.00	3.58	5.10	4.343	1.076
14	2.26	3.23	3.40	4.66	3.388	0.987
15	0.00	0.00	4.59	6.01	5.303	1.003
16	2.83	4.09	3.95	3.10	3.492	0.625
17	0.00	0.00	-0.00	-0.00	0.000	0.000
18	2.76	2.95	5.00	4.18	3.724	1.060
19	3.76	4.24	2.69	4.30	3.748	0.746
20	1.24	1.68	1.88	2.18	1.745	0.395
23	3.47	1.82	2.59	3.04	2.731	0.705
26	1.68	1.55	1.70	2.56	1.873	0.464

AVERAGES FOR BASAL VENT. (L/MIN)

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
1	6.46	4.40	5.97	5.81	5.659	0.885
5	6.92	5.24	6.40	5.64	6.051	0.754
10	6.45	4.73	7.12	6.48	6.197	1.023
11	6.90	5.11	7.18	6.23	6.354	0.918
12	6.59	5.28	6.85	6.10	6.204	0.688
13	6.76	4.37	7.12	5.96	6.052	1.221
14	5.97	4.89	6.35	7.77	6.244	1.189
15	6.77	5.19	6.40	6.46	6.204	0.693
16	7.29	4.52	6.43	5.93	6.043	1.158
17	6.77	4.99	6.15	6.65	6.139	0.814
18	6.53	5.45	5.90	5.70	5.895	0.463
19	6.10	4.85	6.09	5.83	5.716	0.593
20	7.41	5.67	5.49	6.57	6.282	0.886
21	7.49	5.71	6.20	5.48	6.220	0.897
23	6.99	4.91	5.56	7.80	6.314	1.317
27	6.91	4.31	6.05	5.34	5.652	1.102

AVERAGES FOR BASAL VENT. (L/MIN)

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
1	5.76	6.44	6.09	7.46	6.437	0.737
5	6.70	5.98	5.20	6.46	6.087	0.665
10	6.64	6.12	6.55	6.68	6.496	0.256
11	8.13	6.07	6.35	6.65	6.799	0.917
12	7.19	5.64	6.70	6.77	6.574	0.658
13	5.94	5.95	6.49	7.13	6.375	0.563
14	6.96	5.91	6.73	6.69	6.572	0.458
15	7.07	5.86	6.26	6.64	6.458	0.520
16	6.50	5.90	6.22	6.49	6.281	0.283
17	7.24	6.03	6.31	6.80	6.594	0.534
18	6.64	5.39	6.27	6.34	6.159	0.539
19	6.47	5.42	5.52	7.10	6.126	0.801
20	6.65	5.96	6.32	7.07	6.501	0.474
21	7.31	5.97	6.54	5.95	6.440	0.642
23	6.41	5.70	6.46	7.17	6.437	0.598
27	6.48	5.61	5.66	6.83	6.144	0.609

AVERAGES FOR BASAL RESP RATE PER MIN

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
1	14.00	12.00	16.00	12.00	13.500	1.915
5	14.00	12.00	17.00	12.00	13.750	2.363
10	14.00	12.00	18.00	13.00	14.250	2.630
11	14.00	12.00	18.00	17.00	15.250	2.754
12	14.00	14.00	17.00	14.00	14.750	1.500
13	14.00	12.00	19.00	10.00	13.750	3.862
14	14.00	12.00	17.00	17.00	15.000	2.449
15	14.00	12.00	16.00	14.00	14.000	1.633
16	16.00	12.00	13.00	12.00	13.250	1.893
17	15.00	12.00	13.00	17.00	14.250	2.217
18	13.00	13.00	12.00	11.00	12.250	0.957
19	-0.00	10.00	16.00	15.00	13.667	3.215
20	14.00	13.00	13.00	14.00	13.500	0.577
21	14.00	14.00	14.00	11.00	13.250	1.500
23	17.00	13.00	9.00	14.00	13.250	3.304
27	12.00	11.00	17.00	11.00	12.750	2.872

AVERAGES FOR BASAL RESP RATE PER MIN

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
1	13.00	14.00	17.00	18.00	15.500	2.380
5	13.00	14.00	16.00	16.00	14.750	1.500
10	13.00	14.00	17.00	15.00	14.750	1.708
11	13.00	14.00	15.00	15.00	14.250	0.957
12	13.00	11.00	18.00	12.00	13.500	3.109
13	11.00	14.00	14.00	16.00	13.750	2.062
14	13.00	15.00	16.00	16.00	15.000	1.414
15	16.00	18.00	17.00	15.00	16.500	1.291
16	12.00	16.00	19.00	16.00	15.750	2.872
17	13.00	16.00	15.00	17.00	15.250	1.708
18	13.00	13.00	16.00	13.00	13.750	1.500
19	12.00	16.00	15.00	17.00	15.000	2.160
20	13.00	13.00	17.00	15.00	14.500	1.915
21	13.00	14.00	17.00	15.00	14.750	1.708
23	12.00	12.00	13.00	15.00	13.000	1.414
27	13.00	12.00	16.00	16.00	14.250	2.062

AVERAGES FOR BASAL TRUE OXYGEN (PCT)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	4.44	4.37	4.29	4.35	4.362	0.062
5	4.57	3.73	3.68	4.74	4.180	0.553
10	4.18	4.62	3.81	4.58	4.297	0.381
11	4.59	4.34	3.76	3.98	4.167	0.369
12	4.46	4.21	3.73	4.34	4.185	0.320
13	4.38	4.37	3.59	4.28	4.155	0.379
14	4.93	4.50	3.76	3.72	4.227	0.590
15	4.62	4.27	3.57	4.17	4.157	0.437
16	3.66	4.67	3.86	4.27	4.115	0.449
17	4.48	4.13	3.83	3.88	4.080	0.297
18	4.48	4.39	4.04	4.49	4.350	0.212
19	4.68	4.24	3.82	4.30	4.260	0.352
20	4.48	3.88	4.08	4.22	4.165	0.252
21	4.53	4.06	3.72	4.52	4.207	0.392
23	4.57	4.50	4.64	3.98	4.422	0.300
27	4.69	4.41	4.14	4.77	4.502	0.287

AVERAGES FOR BASAL TRUE OXYGEN (PCT)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	4.30	4.48	4.08	4.21	4.267	0.168
5	3.87	4.68	4.33	4.21	4.272	0.334
10	4.12	4.74	4.16	4.56	4.395	0.304
11	3.59	4.42	3.96	4.51	4.120	0.428
12	3.77	4.26	3.82	4.59	4.110	0.388
13	4.54	4.09	4.01	3.83	4.117	0.302
14	4.03	4.28	3.82	4.16	4.072	0.197
15	3.50	4.17	3.83	4.14	3.910	0.314
16	4.03	4.28	3.73	4.23	4.067	0.250
17	3.67	4.22	3.91	4.06	3.965	0.234
18	3.68	4.53	3.69	4.02	3.980	0.399
19	4.05	4.39	3.98	3.73	4.037	0.272
20	3.75	4.13	3.85	3.87	3.900	0.162
21	3.96	4.39	4.02	4.42	4.197	0.241
23	3.88	4.51	3.92	4.04	4.087	0.290
27	4.21	4.62	3.86	3.94	4.157	0.343

AVERAGES FOR BASAL R Q

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	0.82	0.68	0.71	0.76	0.742	0.061
5	0.78	0.85	0.82	0.75	0.800	0.044
10	0.80	0.79	0.85	0.79	0.807	0.029
11	0.79	0.75	0.76	0.86	0.790	0.050
12	0.81	0.80	0.76	0.89	0.815	0.054
13	0.80	0.74	0.76	0.87	0.792	0.057
14	0.75	0.79	0.78	0.92	0.810	0.075
15	0.84	0.69	0.89	0.88	0.825	0.093
16	0.89	0.76	0.95	0.92	0.880	0.084
17	0.70	0.75	0.87	0.92	0.810	0.102
18	0.79	0.75	0.84	0.87	0.812	0.053
19	0.70	0.72	0.89	0.91	0.805	0.110
20	0.79	0.76	0.91	0.89	0.837	0.074
21	0.77	0.76	0.90	0.78	0.802	0.066
23	0.75	0.79	0.86	0.87	0.817	0.057
27	0.77	0.65	0.75	0.76	0.732	0.056

AVERAGES FOR BASAL R Q

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	0.85	0.86	0.66	0.73	0.775	0.097
5	0.80	0.76	0.73	0.79	0.770	0.032
10	0.92	0.73	0.74	0.75	0.785	0.090
11	0.89	0.78	0.71	0.79	0.792	0.074
12	0.82	0.77	0.73	0.85	0.792	0.053
13	0.74	0.74	0.75	0.93	0.790	0.093
14	0.80	0.81	0.77	0.87	0.812	0.042
15	0.92	0.77	0.87	0.86	0.855	0.062
16	0.72	0.71	0.85	0.93	0.802	0.106
17	0.87	0.82	0.89	0.90	0.870	0.036
18	0.84	0.75	0.84	0.90	0.832	0.062
19	0.82	0.75	0.80	0.98	0.837	0.099
20	0.83	0.82	0.83	0.96	0.860	0.067
21	0.77	0.78	0.88	0.78	0.802	0.052
23	0.83	0.76	0.87	0.75	0.802	0.057
27	0.88	0.82	0.81	0.86	0.842	0.033

AVERAGES FOR BASAL OXYGEN CON L/MIN

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	0.29	0.19	0.26	0.25	0.247	0.040
5	0.32	0.20	0.24	0.27	0.253	0.051
10	0.27	0.22	0.27	0.30	0.264	0.033
11	0.32	0.22	0.27	0.25	0.264	0.040
12	0.29	0.22	0.26	0.27	0.259	0.030
13	0.30	0.19	0.25	0.25	0.249	0.044
14	0.29	0.22	0.24	0.29	0.260	0.037
15	0.31	0.22	0.23	0.27	0.258	0.042
16	0.27	0.21	0.25	0.25	0.245	0.024
17	0.30	0.21	0.23	0.26	0.250	0.041
18	0.29	0.24	0.24	0.26	0.256	0.026
19	0.29	0.20	0.23	0.25	0.243	0.034
20	0.33	0.22	0.22	0.28	0.263	0.053
21	0.34	0.23	0.23	0.25	0.262	0.052
23	0.32	0.22	0.26	0.31	0.277	0.046
27	0.32	0.19	0.25	0.25	0.255	0.055

AVERAGES FOR BASAL OXYGEN CON L/MIN

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	0.25	0.29	0.25	0.31	0.275	0.032
5	0.26	0.28	0.22	0.27	0.259	0.024
10	0.27	0.29	0.27	0.30	0.285	0.016
11	0.29	0.27	0.25	0.30	0.278	0.022
12	0.27	0.24	0.26	0.31	0.269	0.030
13	0.27	0.24	0.26	0.27	0.261	0.014
14	0.28	0.25	0.26	0.28	0.267	0.014
15	0.25	0.24	0.24	0.27	0.252	0.016
16	0.26	0.25	0.23	0.27	0.255	0.018
17	0.27	0.25	0.25	0.28	0.261	0.013
18	0.24	0.24	0.23	0.25	0.243	0.010
19	0.26	0.24	0.22	0.27	0.246	0.021
20	0.25	0.25	0.24	0.27	0.253	0.014
21	0.29	0.26	0.26	0.26	0.269	0.014
23	0.25	0.26	0.25	0.29	0.262	0.019
27	0.27	0.26	0.22	0.27	0.255	0.025

AVERAGES FOR BASAL MET ML O-2 MIN KG

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	3.50	3.04	3.83	3.65	3.506	0.336
5	3.91	3.09	3.65	3.95	3.649	0.398
10	3.33	3.48	4.03	4.39	3.807	0.490
11	3.89	3.54	4.05	3.65	3.781	0.231
12	3.64	3.59	3.86	3.91	3.752	0.157
13	3.62	3.05	3.80	3.74	3.552	0.346
14	3.67	3.53	3.57	4.27	3.761	0.347
15	3.87	3.54	3.39	3.96	3.692	0.270
16	3.31	3.34	3.67	3.70	3.505	0.207
17	3.78	3.28	3.49	3.81	3.590	0.252
18	3.66	3.80	3.53	3.77	3.691	0.122
19	3.56	3.25	3.44	3.67	3.481	0.181
20	4.13	3.53	3.33	4.08	3.768	0.399
21	4.16	3.65	3.40	3.63	3.710	0.320
23	3.94	3.45	3.76	4.54	3.922	0.460
27	-0.00	-0.00	-0.00	-0.00	0.000	0.000

AVERAGES FOR BASAL MET ML O-2 MIN KG

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	3.53	4.14	4.13	3.92	3.931	0.287
5	3.77	4.01	3.84	3.46	3.770	0.231
10	3.94	4.21	4.54	3.81	4.126	0.322
11	4.24	3.87	4.24	3.75	4.027	0.254
12	3.94	3.44	4.34	3.91	3.908	0.369
13	3.95	3.50	4.40	3.41	3.815	0.457
14	4.11	3.65	4.41	3.48	3.910	0.425
15	3.62	3.51	4.15	3.44	3.680	0.320
16	3.80	3.64	3.95	3.43	3.704	0.221
17	3.88	3.66	4.19	3.45	3.794	0.316
18	3.54	3.50	3.95	3.18	3.544	0.314
19	3.80	3.47	3.75	3.31	3.583	0.234
20	3.61	3.55	4.18	3.43	3.694	0.333
21	4.22	3.74	4.50	3.31	3.943	0.530
23	3.57	3.65	4.30	3.58	3.777	0.354
27	-0.00	-0.00	-0.00	-0.00	0.000	0.000

AVERAGES FOR REST VENT. (L/MIN)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
4	8.14	8.36	6.81	6.65	7.487	0.883
9	9.98	6.45	8.28	8.25	8.241	1.441
20	-0.00	-0.00	-0.00	8.36	8.363	0.000
22	8.36	7.56	8.02	8.17	8.031	0.341
26	7.01	9.20	7.31	8.63	8.038	1.048

AVERAGES FOR REST VENT. (L/MIN)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
4	8.15	8.51	7.15	7.71	7.883	0.586
9	8.92	7.86	7.95	8.59	8.328	0.512
20	-0.00	-0.00	-0.00	7.69	7.692	0.000
22	8.06	9.29	8.14	8.11	8.400	0.597
26	8.56	7.81	8.47	9.06	8.475	0.512

AVERAGES FOR REST RESP RATE PER MIN

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
4	16.00	19.00	18.00	10.00	15.750	4.031
9	16.00	18.00	16.00	14.00	16.000	1.633
20	16.00	17.00	16.00	16.00	16.250	0.500
22	16.00	16.00	16.00	18.00	16.500	1.000
26	16.00	16.00	16.00	17.00	16.250	0.500

AVERAGES FOR REST RESP RATE PER MIN

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
4	16.00	16.00	14.00	18.00	16.000	1.633
9	16.00	18.00	18.00	20.00	18.000	1.633
20	16.00	18.00	20.00	16.00	17.500	1.915
22	15.00	18.00	20.00	16.00	17.250	2.217
26	16.00	18.00	20.00	15.00	17.250	2.217

AVERAGES FOR REST TRUE OXYGEN (PCT)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
4	4.04	3.77	4.35	4.47	4.157	0.316
9	4.03	4.04	4.08	4.49	4.160	0.221
20	-0.00	-0.00	3.78	3.90	3.840	0.085
22	4.21	4.06	4.11	3.76	4.035	0.194
26	4.37	3.89	4.62	4.06	4.235	0.325

AVERAGES FOR REST TRUE OXYGEN (PCT)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
4	4.21	4.03	4.12	4.63	4.247	0.265
9	3.92	4.14	4.01	4.17	4.060	0.116
20	-0.00	-0.00	3.68	4.47	4.075	0.559
22	3.95	3.97	3.58	4.44	3.985	0.352
26	4.26	4.27	3.67	4.12	4.080	0.282

AVERAGES FOR REST R Q

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
4	0.95	0.86	0.68	0.77	0.815	0.116
9	0.85	0.78	0.84	0.77	0.810	0.041
20	-0.00	-0.00	0.86	0.84	0.850	0.014
22	0.74	0.81	0.94	0.78	0.817	0.087
26	0.77	0.85	0.74	-0.00	0.787	0.057

AVERAGES FOR REST R Q

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
4	0.87	0.81	0.75	0.76	0.797	0.055
9	0.86	0.79	0.82	0.77	0.810	0.039
20	-0.00	-0.00	0.85	0.77	0.810	0.057
22	0.86	0.87	0.92	0.80	0.862	0.049
26	0.79	0.77	0.85	-0.00	0.803	0.042

AVERAGES FOR REST OXYGEN CON. L/MIN

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
4	0.33	0.32	0.30	0.30	0.309	0.016
9	0.40	0.26	0.34	0.37	0.343	0.060
20	-0.00	-0.00	0.29	0.33	0.310	0.023
22	0.35	0.31	0.33	0.31	0.324	0.022
26	0.39	0.36	0.34	0.35	0.360	0.024

AVERAGES FOR REST OXYGEN CON. L/MIN

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
4	0.34	0.34	0.30	0.36	0.334	0.027
9	0.35	0.32	0.32	0.36	0.338	0.019
20	-0.00	-0.00	0.28	0.34	0.313	0.045
22	0.32	0.37	0.29	0.36	0.334	0.037
26	0.36	0.33	0.31	0.37	0.346	0.029

AVERAGES FOR REST MET ML O-2 MIN KG

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
4	4.07	5.00	4.52	4.43	4.504	0.381
9	4.92	4.15	5.05	5.49	4.902	0.557
20	-0.00	-0.00	4.35	4.80	4.577	0.315
22	4.33	4.80	4.82	4.51	4.616	0.236
26	4.84	5.61	4.90	5.17	5.129	0.352

AVERAGES FOR REST MET ML O-2 MIN KG

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
4	4.98	4.94	4.95	4.52	4.848	0.218
9	5.05	4.66	5.35	4.50	4.890	0.384
20	-0.00	-0.00	4.83	4.31	4.571	0.372
22	4.57	5.30	4.98	4.53	4.845	0.362
26	5.31	4.78	5.29	4.63	5.001	0.346

AVERAGES FOR EXER 10 MIN VENTILATION

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	48.27	38.73	36.94	32.42	39.090	6.671
12	41.56	32.02	37.58	35.91	36.767	3.954
15	39.58	36.59	32.58	39.86	37.152	3.389
19	38.79	35.17	32.27	39.79	36.505	3.451
21	40.76	-0.00	32.06	38.71	37.177	4.548
27	40.70	39.08	32.44	38.54	37.690	3.618

AVERAGES FOR EXER 10 MIN VENTILATION

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	31.67	29.60	31.98	39.34	33.148	4.261
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	33.68	30.14	31.54	27.84	30.800	2.452
27	33.00	30.00	31.54	32.18	31.680	1.269

AVERAGES FOR EXER 10 MIN RESP RATE

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	32.00	28.00	24.00	24.00	27.000	3.830
12	32.00	24.00	28.00	24.00	27.000	3.830
15	28.00	28.00	24.00	28.00	27.000	2.000
19	28.00	26.00	24.00	28.00	26.500	1.915
21	28.00	32.00	26.00	28.00	28.500	2.517
27	28.00	32.00	28.00	28.00	29.000	2.000

AVERAGES FOR EXER 10 MIN RESP RATE

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	28.00	26.00	32.00	32.00	29.500	3.000
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	32.00	28.00	28.00	28.00	29.000	2.000
27	28.00	28.00	28.00	28.00	28.000	0.000

AVERAGES FOR EXER 10 MIN TRUE OXYGEN

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	4.92	4.91	4.35	6.10	5.070	0.737
12	4.97	4.66	4.98	5.50	5.027	0.348
15	5.23	4.82	5.40	5.42	5.217	0.278
19	5.36	5.21	5.10	5.56	5.307	0.199
21	5.50	-0.00	5.18	5.57	5.417	0.208
27	5.58	4.43	5.30	5.35	5.165	0.505

AVERAGES FOR EXER 10 MIN TRUE OXYGEN

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	5.12	5.04	4.65	4.97	4.945	0.206
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	5.00	5.19	4.76	5.60	5.137	0.355
27	4.38	5.18	4.92	5.13	4.902	0.366

AVERAGES FOR EXER 10 MIN R Q

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	0.89	0.88	1.02	0.78	0.892	0.098
12	0.85	0.93	0.84	0.86	0.870	0.041
15	0.84	0.90	0.93	0.94	0.902	0.045
19	0.84	0.82	0.95	0.98	0.897	0.079
21	0.81	-0.00	0.95	0.81	0.857	0.081
27	0.80	0.84	0.87	0.85	0.840	0.029

AVERAGES FOR EXER 10 MIN R Q

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	0.80	0.88	0.87	0.86	0.852	0.036
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	0.86	0.90	0.99	0.86	0.902	0.061
27	0.95	0.87	0.85	0.84	0.877	0.050

AVERAGES FOR EXER 10 MIN OXYGEN CONS.

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	2.09	1.69	1.44	1.76	1.741	0.267
12	1.82	1.33	1.67	1.76	1.645	0.219
15	1.84	1.56	1.56	1.93	1.723	0.188
19	1.82	1.64	1.45	1.97	1.721	0.223
21	1.97	-0.00	1.48	1.92	1.790	0.270
27	2.02	1.53	1.54	1.83	1.727	0.239

AVERAGES FOR EXER 10 MIN OXYGEN CONS.

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	1.42	1.33	1.18	1.74	1.420	0.238
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	1.50	1.40	1.34	1.39	1.407	0.067
27	1.28	1.41	1.39	1.47	1.387	0.077

AVERAGES FOR EX 10- ML O-2 MIN KG

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
10	25.74	26.81	21.36	25.93	24.962	2.443
12	22.61	21.55	25.28	25.94	23.843	2.102
15	22.72	24.92	23.28	28.40	24.831	2.555
19	22.69	26.14	21.44	28.80	24.767	3.339
21	24.14	-0.00	21.77	28.14	24.684	3.220
27	-0.00	-0.00	-0.00	-0.00	0.000	0.000

AVERAGES FOR EX 10- ML O-2 MIN KG

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
10	20.56	19.32	19.71	21.81	20.353	1.103
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	21.84	20.00	22.91	17.49	20.560	2.376
27	-0.00	-0.00	-0.00	-0.00	0.000	0.000

AVERAGES FOR EXER 20 MIN VENTILATION

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
10	50.10	44.91	43.24	37.78	44.007	5.076
12	44.66	35.46	41.90	41.68	40.925	3.887
15	43.56	42.68	36.64	43.72	41.650	3.371
19	39.58	37.59	38.32	43.54	39.757	2.652
21	43.88	37.60	33.30	41.72	39.125	4.676
27	41.78	42.60	36.14	43.20	40.930	3.246

AVERAGES FOR EXER 20 MIN VENTILATION

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
10	36.12	33.40	34.18	41.12	36.205	3.470
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	36.84	33.16	33.60	31.60	33.800	2.201
27	34.46	33.42	31.32	35.44	33.660	1.765

AVERAGES FOR EXER 20 MIN RESP RATE

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
10	32.00	32.00	28.00	28.00	30.000	2.309
12	30.00	32.00	32.00	24.00	29.500	3.786
15	30.00	32.00	28.00	26.00	29.000	2.582
19	24.00	24.00	28.00	26.00	25.500	1.915
21	28.00	30.00	28.00	28.00	28.500	1.000
27	30.00	32.00	26.00	28.00	29.000	2.582

AVERAGES FOR EXER 20 MIN RESP RATE

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
10	28.00	30.00	28.00	30.00	29.000	1.155
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	32.00	28.00	30.00	28.00	29.500	1.915
27	28.00	30.00	28.00	28.00	28.500	1.000

AVERAGES FOR EXER 20 MIN TRUE OXYGEN

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
10	4.94	4.40	4.60	5.40	4.835	0.438
12	4.85	4.95	4.78	4.99	4.892	0.095
15	5.00	4.50	5.05	5.10	4.912	0.278
19	5.30	4.98	4.90	5.20	5.095	0.186
21	5.10	4.51	5.04	5.20	4.962	0.309
27	5.45	4.41	5.04	5.14	5.010	0.436

AVERAGES FOR EXER 20 MIN TRUE OXYGEN

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
10	5.05	4.95	4.53	4.98	4.877	0.235
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	4.88	5.13	4.77	5.43	5.052	0.293
27	4.85	5.30	4.90	5.30	5.087	0.246

AVERAGES FOR EXER 20 MIN R Q

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
10	0.87	0.91	0.91	0.83	0.880	0.038
12	0.86	0.86	0.86	0.93	0.877	0.035
15	0.85	0.92	0.96	0.94	0.917	0.048
19	0.83	0.86	0.95	0.92	0.890	0.055
21	0.86	0.93	0.94	0.85	0.895	0.047
27	0.81	0.84	0.87	0.90	0.855	0.039

AVERAGES FOR EXER 20 MIN R Q

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
10	0.81	0.87	0.88	0.86	0.855	0.031
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	0.87	0.89	0.98	0.81	0.887	0.070
27	0.86	0.84	0.86	0.87	0.857	0.013

AVERAGES FOR EXER 20 MIN OXYGEN CONS.

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
10	2.16	1.75	1.76	1.81	1.870	0.198
12	1.90	1.57	1.76	1.84	1.769	0.143
15	1.92	1.69	1.64	1.98	1.807	0.166
19	1.83	1.65	1.64	2.00	1.781	0.171
21	1.98	1.52	1.49	1.92	1.726	0.259
27	2.01	1.64	1.62	1.96	1.806	0.207

AVERAGES FOR EXER 20 MIN OXYGEN CONS.

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
10	1.60	1.47	1.37	1.82	1.563	0.195
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	1.59	1.52	1.42	1.52	1.515	0.070
27	1.57	1.57	1.37	1.67	1.544	0.124

AVERAGES FOR EX 20- ML O-2 MIN KG

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
10	26.73	27.76	26.18	26.66	26.832	0.663
12	23.60	25.47	26.64	27.15	25.713	1.578
15	23.74	27.01	24.38	29.15	26.070	2.494
19	22.84	26.29	24.19	29.26	25.648	2.798
21	24.23	23.88	21.92	28.16	24.548	2.612
27	-0.00	-0.00	-0.00	-0.00	0.000	0.000

AVERAGES FOR EX 20- ML O-2 MIN KG

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
10	23.04	21.34	22.80	22.74	22.482	0.771
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	23.23	21.64	24.40	19.13	22.104	2.281
27	-0.00	-0.00	-0.00	-0.00	0.000	0.000

AVERAGES FOR EXER 30 MIN VENTILATION

INDIVIDUAL DAYS	1	3	5	7	MEAN	STD DEV
10	47.17	43.51	42.43	37.86	42.742	3.835
12	43.29	34.46	41.06	40.92	39.932	3.806
15	41.81	43.34	35.25	40.91	40.327	3.530
19	38.45	35.33	36.42	45.50	38.925	4.570
21	40.88	40.53	41.43	39.34	40.545	0.885
27	41.40	42.17	36.10	40.33	40.000	2.707

AVERAGES FOR EXER 30 MIN VENTILATION

INDIVIDUAL DAYS	2	4	6	8	MEAN	STD DEV
10	36.88	34.14	34.38	39.28	36.170	2.415
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	34.02	33.49	34.56	33.53	33.900	0.502
27	36.33	34.92	32.40	34.58	34.557	1.626

AVERAGES FOR EXER 30 MIN RESP RATE

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	32.00	30.00	30.00	28.00	30.000	1.633
12	30.00	32.00	32.00	28.00	30.500	1.915
15	30.00	32.00	28.00	28.00	29.500	1.915
19	28.00	28.00	28.00	28.00	28.000	0.000
21	28.00	32.00	28.00	28.00	29.000	2.000
27	28.00	30.00	28.00	28.00	28.500	1.000

AVERAGES FOR EXER 30 MIN RESP RATE

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	28.00	32.00	30.00	28.00	29.500	1.915
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	28.00	28.00	30.00	28.00	28.500	1.000
27	28.00	30.00	28.00	26.00	28.000	1.633

AVERAGES FOR EXER 30 MIN TRUE OXYGEN

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	5.00	4.44	4.70	5.41	4.887	0.417
12	4.91	4.97	4.78	5.01	4.917	0.100
15	4.95	4.49	5.06	5.21	4.927	0.311
19	5.32	5.21	4.88	5.15	5.140	0.187
21	5.20	4.54	5.13	5.33	5.050	0.350
27	5.22	4.49	5.17	5.21	5.022	0.356

AVERAGES FOR EXER 30 MIN TRUE OXYGEN

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	4.81	4.75	4.88	5.20	4.910	0.200
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	5.10	5.21	4.78	5.49	5.145	0.294
27	4.85	5.08	5.04	5.43	5.100	0.242

AVERAGES FOR EXER 30 MIN R Q

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	0.85	0.87	0.82	0.81	0.837	0.028
12	0.83	0.84	0.85	0.91	0.857	0.036
15	0.85	0.91	0.95	0.92	0.907	0.042
19	0.80	0.81	0.95	0.91	0.867	0.074
21	0.87	0.90	0.94	0.82	0.882	0.051
27	0.84	0.84	0.83	0.87	0.845	0.017

AVERAGES FOR EXER 30 MIN R Q

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	0.83	0.86	0.83	0.84	0.840	0.014
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	0.85	0.89	0.97	0.84	0.887	0.059
27	0.86	0.86	0.83	0.84	0.847	0.015

AVERAGES FOR EXER 30 MIN OXYGEN CONS.

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	2.06	1.71	1.85	1.81	1.858	0.150
12	1.87	1.61	1.73	1.81	1.753	0.113
15	1.82	1.72	1.58	1.85	1.742	0.124
19	1.79	1.64	1.55	2.06	1.760	0.224
21	1.88	1.64	1.89	1.86	1.814	0.118
27	1.91	1.66	1.66	1.85	1.769	0.130

AVERAGES FOR EXER 30 MIN OXYGEN CONS.

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	1.55	1.44	1.49	1.81	1.572	0.166
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	1.54	1.52	1.47	1.63	1.538	0.069
27	1.56	1.56	1.45	1.67	1.560	0.086

AVERAGES FOR EX 30- ML O-2 MIN KG

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	25.48	27.11	27.55	26.70	26.711	0.888
12	23.13	26.03	26.11	26.77	25.509	1.622
15	22.54	27.36	23.49	27.29	25.170	2.522
19	22.23	26.14	22.90	30.22	25.372	3.651
21	22.99	25.80	27.75	27.19	25.934	2.123
27	-0.00	-0.00	-0.00	-0.00	0.000	0.000

AVERAGES FOR EX 30- ML O-2 MIN KG

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	22.42	20.83	24.87	22.64	22.692	1.661
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	22.42	21.63	25.12	20.50	22.419	1.968
27	-0.00	-0.00	-0.00	-0.00	0.000	0.000

AVERAGES FOR HEART RATE AM RESTING

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
11	54.00	61.00	64.00	60.00	59.750	4.193
13	54.00	52.00	58.00	72.00	59.000	9.018
14	51.00	64.00	60.00	64.00	59.750	6.131
16	60.00	60.00	64.00	76.00	65.000	7.572
17	56.00	60.00	64.00	60.00	60.000	3.266
18	48.00	56.00	60.00	76.00	60.000	11.776

AVERAGES FOR HEART RATE AM 10 MIN EX

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	116.00	163.00	145.00	115.00	134.750	23.415
11	121.00	142.00	132.00	124.00	129.750	9.394
12	122.00	132.00	140.00	116.00	127.500	10.630
13	121.00	144.00	120.00	112.00	124.250	13.769
14	119.00	140.00	140.00	124.00	130.750	10.874
15	132.00	140.00	135.00	128.00	133.750	5.058
16	124.00	136.00	132.00	124.00	129.000	6.000
17	132.00	144.00	132.00	132.00	135.000	6.000
18	108.00	140.00	124.00	128.00	125.000	13.216
19	112.00	152.00	134.00	128.00	131.500	16.523
21	108.00	128.00	120.00	122.00	119.500	8.386
27	106.00	131.00	123.00	125.00	121.250	10.720

AVERAGES FOR HEART RATE AM 10 MIN EX

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	108.00	135.00	133.00	125.00	125.250	12.285
11	-0.00	-0.00	-0.00	-0.00	0.000	0.000
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
13	-0.00	-0.00	-0.00	-0.00	0.000	0.000
14	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
16	-0.00	-0.00	-0.00	-0.00	0.000	0.000
17	-0.00	-0.00	-0.00	-0.00	0.000	0.000
18	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	142.00	124.00	140.00	116.00	130.500	12.583
27	108.00	115.00	125.00	116.00	116.000	6.976

AVERAGES FOR HEART RATE AM 20 MIN EX

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	126.00	171.00	148.00	122.00	141.750	22.603
11	123.00	156.00	138.00	136.00	138.250	13.574
12	130.00	169.00	148.00	127.00	143.500	19.365
13	123.00	148.00	128.00	124.00	130.750	11.701
14	122.00	148.00	144.00	128.00	135.500	12.477
15	135.00	160.00	135.00	136.00	141.500	12.342
16	134.00	144.00	132.00	120.00	132.500	9.849
17	124.00	156.00	136.00	124.00	135.000	15.100
18	112.00	144.00	132.00	124.00	128.000	13.466
19	112.00	144.00	136.00	144.00	134.000	15.144
21	112.00	142.00	120.00	122.00	124.000	12.754
27	107.00	138.00	126.00	129.00	125.000	13.038

AVERAGES FOR HEART RATE AM 20 MIN EX

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	112.00	143.00	133.00	125.00	128.250	13.099
11	-0.00	-0.00	-0.00	-0.00	0.000	0.000
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
13	-0.00	-0.00	-0.00	-0.00	0.000	0.000
14	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
16	-0.00	-0.00	-0.00	-0.00	0.000	0.000
17	-0.00	-0.00	-0.00	-0.00	0.000	0.000
18	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	144.00	132.00	147.00	119.00	135.500	12.767
27	113.00	123.00	130.00	115.00	120.250	7.805

AVERAGES FOR HEART RATE AM 30 MIN EX

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
10	124.00	170.00	126.00	125.00	136.250	22.515
11	125.00	154.00	138.00	136.00	138.250	11.955
12	132.00	170.00	148.00	125.00	143.750	19.973
13	125.00	156.00	122.00	128.00	132.750	15.692
14	122.00	156.00	132.00	134.00	136.000	14.329
15	134.00	164.00	136.00	132.00	141.500	15.089
16	124.00	160.00	132.00	124.00	135.000	17.088
17	136.00	160.00	140.00	136.00	143.000	11.489
18	116.00	148.00	128.00	128.00	130.000	13.266
19	112.00	140.00	134.00	144.00	132.500	14.271
21	116.00	140.00	122.00	128.00	126.500	10.247
27	109.00	140.00	128.00	125.00	125.500	12.767

AVERAGES FOR HEART RATE PM RESTING

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
11	60.00	64.00	64.00	68.00	64.000	3.266
12	60.00	60.00	68.00	64.00	63.000	3.830
13	60.00	52.00	64.00	64.00	60.000	5.657
14	64.00	52.00	56.00	60.00	58.000	5.164
15	61.00	60.00	72.00	68.00	65.250	5.737
16	64.00	64.00	72.00	60.00	65.000	5.033
17	56.00	56.00	68.00	68.00	62.000	6.928
18	52.00	64.00	64.00	60.00	60.000	5.657
19	60.00	56.00	72.00	68.00	64.000	7.303

AVERAGES FOR HEART RATE PM 10 MIN EX

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
11	118.00	138.00	136.00	124.00	129.000	9.592
12	118.00	136.00	136.00	120.00	127.500	9.849
13	118.00	128.00	128.00	112.00	121.500	7.895
14	118.00	128.00	112.00	112.00	117.500	7.550
15	116.00	144.00	128.00	120.00	127.000	12.383
16	124.00	144.00	136.00	112.00	129.000	14.000
17	124.00	146.00	136.00	120.00	131.500	11.818
18	112.00	136.00	124.00	112.00	121.000	11.489
19	112.00	144.00	140.00	120.00	129.000	15.449

AVERAGES FOR HEART RATE PM 20 MIN EX

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
11	121.00	146.00	136.00	136.00	134.750	10.308
12	121.00	143.00	136.00	132.00	133.000	9.201
13	121.00	150.00	128.00	120.00	129.750	13.961
14	122.00	148.00	112.00	124.00	126.500	15.264
15	112.00	156.00	128.00	120.00	129.000	19.149
16	134.00	156.00	140.00	112.00	135.500	18.212
17	124.00	144.00	132.00	124.00	131.000	9.452
18	116.00	144.00	132.00	116.00	127.000	13.614
19	116.00	152.00	136.00	120.00	131.000	16.452

AVERAGES FOR HEART RATE PM 30 MIN EX

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
11	120.00	150.00	148.00	136.00	138.500	13.796
12	120.00	156.00	144.00	136.00	139.000	15.100
13	120.00	156.00	135.00	120.00	132.750	17.037
14	120.00	160.00	132.00	120.00	133.000	18.868
15	120.00	160.00	124.00	116.00	130.000	20.265
16	128.00	156.00	132.00	116.00	133.000	16.773
17	124.00	152.00	132.00	124.00	133.000	13.216
18	112.00	148.00	132.00	116.00	127.000	16.452
19	116.00	156.00	136.00	120.00	132.000	18.184

AVERAGES FOR K40 (ENDOG) BODY MASS

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
5	240.00	182.00	174.00	202.00	199.500	29.456
10	220.00	148.00	144.00	143.00	163.750	37.562
20	187.00	133.00	142.00	174.00	159.000	25.652
26	186.00	136.00	159.00	164.00	161.250	20.516

AVERAGES FOR L.B.M. IMMERSION (KG)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	70.56	54.56	57.81	64.33	61.815	7.106
9	70.41	54.47	56.60	62.66	61.035	7.148
20	69.80	53.10	56.22	62.69	60.452	7.402
26	70.08	52.92	57.65	62.86	60.877	7.357

AVERAGES FOR LBM SKIN FOLDS (KG)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
9	72.55	54.40	59.65	61.56	62.040	7.633
20	71.82	54.47	60.59	61.47	62.087	7.197
26	72.60	55.54	61.28	61.43	62.712	7.139

AVERAGES FOR PERCENT BODY FAT (IMERS)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	13.60	14.00	17.60	18.60	15.950	2.521
9	13.80	14.20	15.50	7.90	12.850	3.379
20	13.40	15.40	16.50	7.70	13.250	3.916
26	14.10	17.20	15.70	7.60	13.650	4.227

AVERAGES FOR HEART RATE AM 30 MIN EX

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
10	120.00	150.00	132.00	125.00	131.750	13.124
11	-0.00	-0.00	-0.00	-0.00	0.000	0.000
12	-0.00	-0.00	-0.00	-0.00	0.000	0.000
13	-0.00	-0.00	-0.00	-0.00	0.000	0.000
14	-0.00	-0.00	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	-0.00	-0.00	0.000	0.000
16	-0.00	-0.00	-0.00	-0.00	0.000	0.000
17	-0.00	-0.00	-0.00	-0.00	0.000	0.000
18	-0.00	-0.00	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	-0.00	-0.00	0.000	0.000
21	142.00	140.00	144.00	128.00	138.500	7.188
27	112.00	124.00	137.00	117.00	122.500	10.847

AVERAGES FOR K40 (ENDOG) BODY MASS

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
5	187.00	178.00	176.00	210.00	187.750	15.586
10	182.00	162.00	158.00	186.00	172.000	14.048
20	138.00	144.00	162.00	199.00	160.750	27.464
26	165.00	179.00	145.00	184.00	168.250	17.462

AVERAGES FOR L.B.M. IMMERSION (KG)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	58.85	57.14	55.73	68.77	60.122	5.904
9	59.66	57.29	54.39	67.51	59.712	5.627
20	57.20	55.78	52.06	67.79	58.207	6.746
26	58.12	56.25	53.71	68.74	59.205	6.609

AVERAGES FOR LBM SKIN FOLDS (KG)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
9	61.65	60.44	53.68	69.73	61.375	6.582
20	61.30	60.85	52.29	69.61	61.012	7.074
26	61.27	60.90	53.00	70.60	61.443	7.199

AVERAGES FOR PERCENT BODY FAT (IMERS)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	15.70	18.00	17.40	15.00	16.525	1.408
9	14.10	18.00	8.30	15.30	13.925	4.089
20	16.60	19.50	10.00	14.80	15.225	3.985
26	15.80	19.00	8.50	15.00	14.575	4.403

AVERAGES FOR PERCENT BODY FAT (SK FL)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
9	11.20	14.30	10.00	9.80	11.325	2.077
20	10.80	13.30	10.00	9.50	10.900	1.687
26	11.20	13.30	10.40	9.70	11.150	1.559

AVERAGES FOR PERCENT BODY FAT (SK FL)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
9	11.10	13.50	9.70	12.70	11.750	1.692
20	11.00	12.40	9.60	12.50	11.375	1.367
26	10.90	12.50	9.70	12.70	11.450	1.418

AVERAGES FOR CIRCUM CALF (CM)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
9	40.20	32.90	35.00	35.80	35.975	3.071
20	39.40	33.20	35.40	34.40	35.600	2.688
26	40.30	34.30	35.60	35.60	36.450	2.639

AVERAGES FOR CIRCUM CALF (CM)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
9	33.70	33.20	32.40	36.50	33.950	1.782
20	34.20	33.40	32.00	35.60	33.800	1.506
26	33.80	33.20	31.40	36.30	33.675	2.025

AVERAGES FOR CIRCUM THIGH (CM)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
9	54.80	48.80	49.30	45.30	49.550	3.926
20	55.50	46.90	49.60	45.40	49.350	4.453
26	56.50	47.10	51.50	45.60	50.185	4.905

AVERAGES FOR CIRCUM THIGH (CM)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
9	51.40	51.00	46.40	55.10	50.975	3.565
20	50.50	49.80	44.40	54.30	49.750	4.078
26	51.40	49.00	44.40	54.90	49.925	4.408

AVERAGES FOR CIRCUM UP ARM RELAX (CM)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
9	29.70	24.80	25.20	24.00	25.925	2.566
20	30.70	24.30	25.20	24.20	26.100	3.099
26	30.50	24.60	25.40	23.50	26.000	3.099

AVERAGES FOR CIRCUM UP ARM RELAX (CM)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
9	25.90	26.80	23.60	28.40	26.175	2.004
20	25.70	26.50	23.20	29.50	26.225	2.597
26	26.10	26.20	23.40	29.60	26.325	2.540

AVERAGES FOR CIRCUM UP ARM CONTR (CM)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
9	36.70	26.80	29.80	27.80	30.275	4.461
20	34.50	27.30	29.80	28.20	29.950	3.205
26	35.50	27.10	30.40	28.30	30.325	3.710

AVERAGES FOR CIRCUM UP ARM CONTR (CM)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
9	28.90	29.40	28.20	31.40	29.475	1.374
20	28.60	29.90	29.20	33.00	30.175	1.957
26	29.00	30.40	28.50	33.40	30.325	2.202

AVERAGES FOR CIRCUM CHEST (CM)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
9	88.50	81.40	82.10	83.00	83.750	3.234
20	88.50	82.30	81.50	82.70	83.750	3.206
26	88.40	82.30	82.10	82.00	83.700	3.136

AVERAGES FOR CIRCUM CHEST (CM)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
9	86.60	86.50	79.90	89.40	85.600	4.031
20	82.00	85.40	78.70	90.30	84.100	4.956
26	83.90	85.50	79.50	89.30	84.550	4.058

AVERAGES FOR CIRCUM WAIST (CM)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
9	77.80	79.30	70.90	72.40	75.100	4.077
20	76.90	72.30	66.80	69.80	71.450	4.273
26	77.30	73.30	69.50	68.80	72.225	3.919

AVERAGES FOR CIRCUM WAIST (CM)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
9	71.70	73.80	78.50	80.30	76.075	4.002
20	72.80	74.30	62.80	77.50	71.850	6.344
26	72.70	77.70	64.10	78.60	73.275	6.644

AVERAGES FOR STRENGTH HAND GRIP (KG)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
9	136.71	111.35	126.79	112.46	121.832	12.159
20	130.10	110.25	126.79	108.05	118.901	9.074
26	119.07	116.87	123.48	102.53	115.494	9.055

AVERAGES FOR STRENGTH HAND GRIP (KG)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
9	110.25	86.00	110.25	123.48	107.499	15.620
20	119.07	103.64	112.46	132.30	116.873	12.077
26	116.87	101.43	114.66	130.10	115.766	11.742

AVERAGES FOR STRENGTH KNEE EXT (LBS)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
9	200.00	130.00	190.00	190.00	177.500	32.021
20	161.32	126.67	220.00	210.00	179.596	43.558
26	190.00	153.33	186.67	240.00	192.503	35.743

AVERAGES FOR STRENGTH KNEE EXT (LBS)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
9	140.00	140.00	156.67	210.00	161.670	33.762
20	136.67	149.33	140.00	163.33	147.333	11.491
26	150.00	170.00	156.67	205.00	170.422	24.497

AVERAGES FOR STRENGTH PLANT FL (LBS)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
9	373.33	166.67	230.00	286.67	264.172	87.743
20	336.67	195.00	293.33	293.33	279.579	59.981
26	373.33	205.00	300.00	346.67	306.250	74.000

AVERAGES FOR STRENGTH PLANT FL (LBS)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
9	183.33	190.00	220.00	293.33	221.67	50.76
20	230.00	185.67	230.00	353.33	249.75	72.42
26	266.67	180.00	230.00	386.67	265.84	88.04

AVERAGES FOR VITAL CAPACITY (LITERS)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	5.69	3.91	4.66	5.90	5.040	0.928
9	5.85	4.08	4.52	5.86	5.077	0.916
20	5.97	4.09	4.42	5.75	5.057	0.941
26	5.81	3.92	4.61	5.90	5.060	0.961

AVERAGES FOR VITAL CAPACITY (LITERS)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	5.11	4.51	4.15	5.74	4.877	0.698
9	5.21	5.04	4.18	5.64	5.017	0.613
20	5.11	4.75	4.02	5.45	4.832	0.612
26	5.11	5.00	4.11	5.51	4.933	0.591

AVERAGES FOR BASAL HEART RATE (BEATS /MIN)

INDIVIDUAL	1	3	5	7	MEAN	STD DEV
DAYS						
1	48.00	50.00	52.00	54.00	51.000	2.582
5	54.00	50.00	47.00	55.00	51.500	3.697
10	46.00	48.00	49.00	59.00	50.500	5.802
11	50.00	48.00	62.00	59.00	54.832	6.801
12	44.00	52.00	54.00	52.00	50.500	4.435
13	42.00	48.00	53.00	49.00	48.012	4.546
14	44.00	51.00	49.00	53.00	49.333	3.863
15	44.00	48.00	49.00	56.00	49.333	4.992
16	50.00	46.00	53.00	50.00	49.689	2.837
17	48.00	52.00	52.00	51.00	50.722	1.894
18	46.00	48.00	51.00	55.00	50.000	3.916
19	44.00	53.00	45.00	50.00	48.025	4.243
20	60.00	52.00	48.00	54.00	53.541	5.000
21	47.00	55.00	48.00	54.00	51.048	4.083
23	44.00	56.00	60.00	57.00	54.213	7.042
27	46.00	53.00	53.00	52.00	51.029	3.367

AVERAGES FOR BASAL HEART RATE (BEATS/MIN)

INDIVIDUAL	2	4	6	8	MEAN	STD DEV
DAYS						
1	-0.00	60.00	48.00	60.00	-0.000	-0.000
5	74.00	56.00	56.00	54.00	60.000	9.381
10	60.00	60.00	56.00	64.00	60.025	3.266
11	64.00	54.00	54.00	57.00	57.333	4.717
12	52.00	52.00	52.00	66.00	55.580	7.000
13	52.00	56.00	52.00	67.00	56.821	7.089
14	58.00	56.00	50.00	54.00	54.487	3.416
15	60.00	56.00	52.00	51.00	54.844	4.114
16	56.00	60.00	58.00	64.00	59.503	3.416
17	58.00	56.00	54.00	71.00	59.819	7.654
18	58.00	54.00	56.00	54.00	55.500	1.915
19	62.00	56.00	48.00	62.00	57.013	6.633
20	52.00	50.00	51.00	64.00	54.222	6.551
21	76.00	61.00	55.00	63.00	63.803	8.846
23	72.00	60.00	58.00	64.00	63.500	6.191
27	68.00	60.00	51.00	62.00	60.333	7.042

AVERAGES FOR NA SERUM CONC. (MEQ/L)

INDIVIDUAL DAYS	10	12	MEAN	STD DEV
1	140.20	140.50	140.350	0.212
5	144.60	136.00	140.300	6.081
10	137.30	141.60	139.450	3.041
12	146.40	139.50	142.950	4.879
15	140.00	142.80	141.400	1.980
19	135.20	136.80	136.000	1.131
21	139.20	135.50	137.350	2.616
23	137.00	128.70	132.850	5.869
27	140.50	129.50	135.000	7.778

AVERAGES FOR K SERUM CONC. (MEQ/L)

INDIVIDUAL DAYS	10	12	MEAN	STD DEV
1	3.58	3.61	3.595	0.021
5	3.76	5.74	4.750	1.400
10	3.21	3.93	3.570	0.509
12	3.28	4.06	3.670	0.552
15	3.20	4.01	3.605	0.573
19	2.76	3.60	3.180	0.594
21	3.27	4.69	3.980	1.004
23	3.30	4.25	3.775	0.672
27	4.02	4.30	4.160	0.198

AVERAGES FOR CL SERUM CONC. (MEQ/L)

INDIVIDUAL DAYS	10	12	MEAN	STD DEV
1	102.50	101.00	101.750	1.061
5	108.00	106.50	107.250	1.061
10	97.50	104.50	101.000	4.950
12	100.00	106.00	103.000	4.243
15	101.00	107.50	104.250	4.596
19	103.50	102.50	103.000	0.707
21	98.00	108.00	103.000	7.071
23	99.50	101.00	100.250	1.061
27	98.00	106.50	102.250	6.010

AVERAGES FOR OSMOLARITY SERUM (OSM/L)

INDIVIDUAL DAYS	10	12	MEAN	STD DEV
1	291.00	283.10	287.050	5.586
5	299.10	294.00	296.550	3.606
10	287.70	283.80	285.750	2.758
12	292.70	287.80	290.250	3.465
15	290.00	293.10	291.550	2.192
19	287.70	292.50	290.100	3.394
21	278.90	288.20	283.550	6.576
23	282.20	277.50	279.850	3.323
27	280.20	280.70	280.450	0.354

AVERAGES FOR OSMOL POST EX SERUM

INDIVIDUAL DAYS	10	12	MEAN	STD DEV
10	290.30	274.40	282.350	11.243
12	292.70	287.80	290.250	3.465
15	-0.00	-0.00	0.000	0.000
19	285.80	282.50	284.150	2.333
21	-0.00	-0.00	0.000	0.000
27	269.10	275.90	272.500	4.808

AVERAGES FOR CREATNINE SERUM (GM PCT)

INDIVIDUAL DAYS	10	12	MEAN	STD DEV
10	0.85	0.91	0.880	0.042
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	0.80	0.82	0.810	0.014
21	-0.00	-0.00	0.000	0.000
27	0.94	0.82	0.880	0.085

AVERAGES FOR NA URINARY 24 HR (MEQ/L)

INDIVIDUAL DAYS	10	12	MEAN	STD DEV
1	249.00	256.00	252.500	4.950
5	287.00	230.00	258.500	40.305
9	228.00	244.00	236.000	11.314
10	132.00	201.00	166.500	48.790
11	200.00	263.00	231.500	44.548
12	-0.00	257.00	257.000	0.000
13	-0.00	242.00	242.000	0.000
14	224.00	221.00	222.500	2.121
15	-0.00	237.00	237.000	0.000
16	221.00	261.00	241.000	28.284
17	-0.00	209.00	209.000	0.000
18	269.00	263.00	266.000	4.243
19	108.00	183.00	145.500	53.033
20	227.00	174.00	200.500	37.477
23	176.00	97.00	136.500	55.861
26	163.00	89.00	126.000	52.326

AVERAGES FOR NA URINE OUTPT (MEQ/DAY)

INDIVIDUAL DAYS	12	MEAN	STD DEV
1	267.62	267.624	0.000
5	226.28	226.284	0.000
9	254.57	254.569	0.000
10	-0.00	0.000	0.000
11	315.49	315.492	0.000
12	352.48	352.480	0.000
13	234.99	234.987	0.000
14	241.51	241.514	0.000
15	226.28	226.284	0.000
16	308.96	308.964	0.000
17	224.11	224.108	0.000
18	343.78	343.777	0.000
19	189.30	189.295	0.000
20	189.30	189.295	0.000
23	63.53	63.534	0.000
26	159.27	159.269	0.000

AVERAGES FOR NA URINE RATE (UEQ/MIN)

INDIVIDUAL DAYS	12	MEAN	STD DEV
1	185.00	185.000	0.000
5	158.00	158.000	0.000
9	177.00	177.000	0.000
10	135.00	135.000	0.000
11	220.00	220.000	0.000
12	244.00	244.000	0.000
13	162.00	162.000	0.000
14	168.00	168.000	0.000
15	156.00	156.000	0.000
16	215.00	215.000	0.000
17	156.00	156.000	0.000
18	239.00	239.000	0.000
19	131.00	131.000	0.000
20	131.00	131.000	0.000
23	44.00	44.000	0.000
26	111.00	111.000	0.000

AVERAGES FOR NA URINE RATE POST EX.

INDIVIDUAL DAYS	12	MEAN	STD DEV
10	184.00	184.000	0.000
12	-0.00	0.000	0.000
15	-0.00	0.000	0.000
19	180.00	180.000	0.000
21	-0.00	0.000	0.000
27	195.00	195.000	0.000

AVERAGES FOR K URINARY 24 HR (MEQ/L)

INDIVIDUAL DAYS	10	12	MEAN	STD DEV
1	111.00	88.00	99.500	16.263
5	63.00	68.00	65.500	3.536
9	30.00	62.00	46.000	22.627
10	27.00	48.00	37.500	14.849
11	46.00	44.00	45.000	1.414
12	-0.00	64.00	64.000	0.000
13	-0.00	57.00	57.000	0.000
14	53.00	64.00	58.500	7.778
15	-0.00	67.00	67.000	0.000
16	69.00	57.00	63.000	8.485
17	-0.00	59.00	59.000	0.000
18	54.00	63.00	58.500	6.364
19	23.00	45.00	34.000	15.556
20	29.00	47.00	38.000	12.728
23	97.00	44.00	70.500	37.477
26	43.00	16.00	29.500	19.092

AVERAGES FOR K URINE OUTPUT (MEQ/DAY)

INDIVIDUAL DAYS	12	MEAN	STD DEV
1	89.51	89.514	0.000
5	66.50	66.496	0.000
9	63.94	63.939	0.000
10	-0.00	0.000	0.000
11	53.71	53.708	0.000
12	86.96	86.957	0.000
13	56.27	56.266	0.000
14	63.94	63.939	0.000
15	69.05	69.054	0.000
16	63.94	63.939	0.000
17	81.84	81.841	0.000
18	46.04	46.036	0.000
19	-0.00	0.000	0.000
20	56.27	56.266	0.000
23	28.13	28.133	0.000
26	28.13	28.133	0.000

AVERAGES FOR K URINE RATE (UEQ/MIN)

INDIVIDUAL	12	MEAN	STD DEV
DAYS			
1	58.50	58.500	0.000
5	46.00	46.000	0.000
9	45.00	45.000	0.000
10	34.00	34.000	0.000
11	36.40	36.400	0.000
12	61.00	61.000	0.000
13	33.30	33.300	0.000
14	48.50	48.500	0.000
15	44.50	44.500	0.000
16	47.00	47.000	0.000
17	44.00	44.000	0.000
18	57.00	57.000	0.000
19	32.00	32.000	0.000
20	35.80	35.800	0.000
23	20.30	20.300	0.000
26	19.30	19.300	0.000

AVERAGES FOR K URINE RATE POST EX

INDIVIDUAL	12	MEAN	STD DEV
DAYS			
10	59.00	59.000	0.000
12	-0.00	0.000	0.000
15	-0.00	0.000	0.000
19	76.00	76.000	0.000
21	-0.00	0.000	0.000
27	129.00	129.000	0.000

AVERAGES FOR CL URINARY 24 HR (MEQ/L)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
1	134.00	173.00	153.500	27.577
5	385.00	218.00	301.500	118.087
9	137.00	238.00	187.500	71.418
11	161.00	307.00	234.000	103.238
12	-0.00	373.00	373.000	0.000
13	-0.00	253.00	253.000	0.000
14	185.00	246.00	215.500	43.134
15	-0.00	230.00	230.000	0.000
16	153.00	307.00	230.000	108.894
17	-0.00	228.00	228.000	0.000
18	167.00	334.00	250.500	118.087
19	-0.00	184.00	184.000	0.000
20	197.00	202.00	199.500	3.536
23	90.00	159.00	124.500	48.790
26	131.00	158.00	144.500	19.092

AVERAGES FOR CL URINE OUTPT (MEQ/DAY

INDIVIDUAL	12	MEAN	STD DEV
DAYS			
1	173.45	173.450	0.000
5	218.86	218.857	0.000
9	238.32	238.317	0.000
11	301.77	301.774	0.000
12	375.10	375.102	0.000
13	253.83	253.829	0.000
14	246.50	246.496	0.000
15	229.86	229.856	0.000
16	301.77	301.774	0.000
17	227.88	227.882	0.000
18	332.80	332.797	0.000
19	183.88	183.885	0.000
20	200.24	200.243	0.000
23	159.07	159.066	0.000
26	157.94	157.938	0.000

AVERAGES FOR CL URINE RATE (UEQ/MIN)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
1	93.00	120.00	106.500	19.092
5	267.00	151.00	209.000	82.024
9	95.00	165.00	130.000	49.497
11	112.00	213.00	162.500	71.418
12	-0.00	259.00	259.000	0.000
13	-0.00	176.00	176.000	0.000
14	128.00	171.00	149.500	30.406
15	-0.00	160.00	160.000	0.000
16	106.00	213.00	159.500	75.660
17	-0.00	158.00	158.000	0.000
18	116.00	232.00	174.000	82.024
19	-0.00	128.00	128.000	0.000
20	137.00	140.00	138.500	2.121
23	63.00	110.00	86.500	33.234
26	91.00	110.00	100.500	13.435

AVERAGES FOR CL URINE RATE POST EX

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	262.00	129.00	195.500	94.045
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	-0.00	180.00	180.000	0.000
21	-0.00	-0.00	0.000	0.000
27	-0.00	366.00	366.000	0.000

AVERAGES FOR OSMOL URINE 24 HR (MO/L)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
1	1195.00	994.00	1094.500	142.128
5	1250.00	1263.00	1256.500	9.192
9	1166.00	1487.00	1326.500	226.981
11	1196.00	1153.00	1174.500	30.406
12	-0.00	-0.00	0.000	0.000
13	-0.00	-0.00	0.000	0.000
14	1217.00	1266.00	1241.500	34.648
16	1218.00	1368.00	1293.000	106.066
18	1210.00	1250.00	1230.000	28.284
20	930.00	-0.00	930.000	0.000
23	1140.00	1000.00	1070.000	98.995
26	740.00	-0.00	740.000	0.000

AVERAGES FOR OSMOL URINE POST EX

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	629.00	541.00	585.000	62.225
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	-0.00	-0.00	0.000	0.000
21	-0.00	-0.00	0.000	0.000
27	233.00	-0.00	233.000	0.000

AVERAGES FOR CREATNINE UR. 24HR (MG()

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
1	284.00	186.00	235.000	69.296
5	-0.00	216.00	216.000	0.000
9	222.00	195.00	208.500	19.092
11	246.00	177.00	211.500	48.790
12	-0.00	174.00	174.000	0.000
13	-0.00	195.00	195.000	0.000
14	249.00	198.00	223.500	36.062
16	-0.00	177.00	177.000	0.000
18	-0.00	174.00	174.000	0.000
20	180.00	183.00	181.500	2.121
23	311.00	276.00	293.500	24.749

AVERAGES FOR CREATNINE UR. 24HR (GMS)

INDIVIDUAL	12	MEAN	STD DEV
DAYS			
1	1.94	1.940	0.000
5	2.08	2.080	0.000
9	2.03	2.030	0.000
11	2.12	2.120	0.000
12	2.38	2.380	0.000
13	1.89	1.890	0.000
14	2.16	2.160	0.000
16	2.10	2.100	0.000
18	2.28	2.280	0.000
20	1.99	1.990	0.000
23	1.81	1.810	0.000

AVERAGES FOR BASAL VENT. (L/MIN)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
1	6.08	4.75	5.419	0.940
5	6.53	4.63	5.581	1.340
10	6.03	6.37	6.201	0.245
11	8.61	8.47	8.542	0.098
12	5.80	5.15	5.476	0.454
13	-0.00	-0.00	0.000	0.000
14	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
16	5.92	5.30	5.609	0.443
17	-0.00	-0.00	0.000	0.000
18	-0.00	-0.00	0.000	0.000
19	5.91	5.26	5.589	0.460
20	6.05	5.70	5.875	0.252
21	-0.00	5.97	5.968	0.000
23	5.42	5.13	5.274	0.208
27	5.93	5.93	5.931	0.001

AVERAGES FOR BASAL RESP RATE PER MIN

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
1	14.00	5.00	9.500	6.364
5	14.00	8.00	11.000	4.243
10	18.00	12.00	15.000	4.243
11	14.00	18.00	16.000	2.828
12	14.00	9.00	11.500	3.536
13	14.00	11.00	12.500	2.121
14	14.00	11.00	12.500	2.121
15	14.00	11.00	12.500	2.121
16	13.00	8.00	10.500	3.536
17	14.00	11.00	12.500	2.121
18	14.00	11.00	12.500	2.121
19	16.00	9.00	12.500	4.950
20	18.00	10.00	14.000	5.657
21	14.00	10.00	12.000	2.828
23	9.00	8.00	8.500	0.707
27	12.00	12.00	12.000	0.000

AVERAGES FOR BASAL TRUE OXYGEN (PCT)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
1	4.45	5.27	4.860	0.580
5	4.02	4.82	4.420	0.566
10	4.10	4.28	4.190	0.127
11	4.02	3.76	3.890	0.184
12	4.24	4.26	4.250	0.014
13	-0.00	-0.00	0.000	0.000
14	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
16	4.23	4.57	4.400	0.240
17	-0.00	-0.00	0.000	0.000
18	-0.00	-0.00	0.000	0.000
19	4.29	4.37	4.330	0.057
20	4.43	4.30	4.365	0.092
21	-0.00	4.32	4.320	0.000
23	4.48	4.44	4.460	0.028
27	4.41	4.14	4.275	0.191

AVERAGES FOR BASAL R Q

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
1	0.79	0.74	0.765	0.035
5	0.86	0.70	0.780	0.113
10	0.85	0.79	0.820	0.042
11	0.86	0.88	0.870	0.014
12	0.83	0.84	0.835	0.007
13	-0.00	-0.00	0.000	0.000
14	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
16	0.76	0.80	0.780	0.028
17	-0.00	-0.00	0.000	0.000
18	-0.00	-0.00	0.000	0.000
19	0.84	0.84	0.840	0.000
20	0.81	0.80	0.805	0.007
21	-0.00	0.76	0.760	0.000
23	0.82	0.75	0.785	0.049
27	0.84	0.79	0.815	0.035

AVERAGES FOR BASAL OXYGEN CON L/MIN

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
1	0.27	0.25	0.261	0.014
5	0.26	0.22	0.242	0.028
10	0.25	0.27	0.260	0.018
11	0.35	0.32	0.332	0.019
12	0.25	0.22	0.233	0.018
13	-0.00	-0.00	0.000	0.000
14	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
16	0.25	0.24	0.246	0.006
17	-0.00	-0.00	0.000	0.000
18	-0.00	-0.00	0.000	0.000
19	0.25	0.23	0.242	0.017
20	0.27	0.24	0.256	0.016
21	-0.00	0.26	0.258	0.000
23	0.24	0.23	0.236	0.011
27	0.26	0.25	0.254	0.011

AVERAGES FOR REST VENT. (L/MIN)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
4	7.46	5.95	6.707	1.071
9	7.80	7.66	7.728	0.100
20	-0.00	7.10	7.099	0.000
22	7.41	6.39	6.900	0.720
26	7.07	7.03	7.053	0.028

AVERAGES FOR REST RESP RATE PER MIN

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
4	18.00	8.00	13.000	7.071
9	17.00	12.00	14.500	3.536
20	18.00	14.00	16.000	2.828
22	16.00	10.00	13.000	4.243
26	13.00	8.00	10.500	3.536

AVERAGES FOR REST TRUE OXYGEN (PCT)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
4	3.68	4.78	4.230	0.778
9	4.37	4.37	4.370	0.000
20	-0.00	4.08	4.080	0.000
22	4.07	4.31	4.190	0.170
26	4.06	4.34	4.200	0.198

AVERAGES FOR REST R Q

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
4	0.82	0.78	0.800	0.028
9	0.80	0.86	0.830	0.042
20	-0.00	0.76	0.760	0.000
22	0.87	0.75	0.810	0.085
26	0.87	-0.00	0.870	0.000

AVERAGES FOR REST OXYGEN CON. L/MIN

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
4	0.27	0.28	0.280	0.006
9	0.34	0.34	0.338	0.004
20	-0.00	0.29	0.290	0.000
22	0.30	0.27	0.288	0.019
26	0.29	0.30	0.296	0.013

AVERAGES FOR EXER 10 MIN VENTILATION

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	23.60	44.25	33.925	14.602
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	29.83	47.35	38.590	12.389
21	-0.00	-0.00	0.000	0.000
27	26.00	38.58	32.290	8.895

AVERAGES FOR EXER 10 MIN RESP RATE

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	28.00	24.00	26.000	2.828
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	28.00	24.00	26.000	2.828
21	-0.00	-0.00	0.000	0.000
27	26.00	28.00	27.000	1.414

AVERAGES FOR EXER 10 MIN TRUE OXYGEN

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	-0.00	4.28	4.280	0.000
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	5.58	4.59	5.085	0.700
21	-0.00	-0.00	0.000	0.000
27	5.68	4.49	5.085	0.841

AVERAGES FOR EXER 10 MIN R Q

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	-0.00	0.91	0.910	0.000
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	0.79	1.02	0.905	0.163
21	-0.00	-0.00	0.000	0.000
27	0.79	0.95	0.870	0.113

AVERAGES FOR EXER 10 MIN OXYGEN CONS.

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	-0.00	1.69	1.691	0.000
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	1.50	1.61	1.550	0.078
21	-0.00	-0.00	0.000	0.000
27	1.32	1.54	1.431	0.158

AVERAGES FOR EXER 20 MIN VENTILATION

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	30.20	49.23	39.715	13.456
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	34.42	37.80	36.110	2.390
21	-0.00	-0.00	0.000	0.000
27	26.60	41.64	34.120	10.635

AVERAGES FOR EXER 20 MIN RESP RATE

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	20.00	28.00	24.000	5.657
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	28.00	28.00	28.000	0.000
21	-0.00	-0.00	0.000	0.000
27	26.00	28.00	27.000	1.414

AVERAGES FOR EXER 20 MIN TRUE OXYGEN

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	5.00	4.02	4.510	0.693
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	5.55	4.33	4.940	0.863
21	-0.00	-0.00	0.000	0.000
27	5.50	4.49	4.995	0.714

AVERAGES FOR EXER 20 MIN R Q

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	0.83	0.90	0.865	0.049
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	0.80	0.99	0.895	0.134
21	-0.00	-0.00	0.000	0.000
27	0.84	0.92	0.880	0.057

AVERAGES FOR EXER 20 MIN OXYGEN CONS.

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	1.34	1.78	1.560	0.306
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	1.71	1.81	1.756	0.070
21	-0.00	-0.00	0.000	0.000
27	1.30	1.66	1.479	0.250

AVERAGES FOR EXER 30 MIN VENTILATION

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	31.54	47.33	39.435	11.165
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	36.13	46.51	41.320	7.340
21	-0.00	-0.00	0.000	0.000
27	27.46	38.08	32.770	7.509

AVERAGES FOR EXER 30 MIN RESP RATE

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	28.00	28.00	28.000	0.000
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	28.00	28.00	28.000	0.000
21	-0.00	-0.00	0.000	0.000
27	26.00	30.00	28.000	2.828

AVERAGES FOR EXER 30 MIN TRUE OXYGEN

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	5.35	4.22	4.785	0.799
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	5.41	4.42	4.915	0.700
21	-0.00	-0.00	0.000	0.000
27	5.50	4.62	5.060	0.622

AVERAGES FOR EXER 30 MIN R Q

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	0.80	0.88	0.840	0.057
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	0.82	0.98	0.900	0.113
21	-0.00	-0.00	0.000	0.000
27	0.83	0.88	0.855	0.035

AVERAGES FOR EXER 30 MIN OXYGEN CONS.

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
10	1.49	1.77	1.631	0.199
12	-0.00	-0.00	0.000	0.000
15	-0.00	-0.00	0.000	0.000
19	1.74	1.81	1.778	0.049
21	-0.00	-0.00	0.000	0.000
27	1.34	1.56	1.448	0.151

AVERAGES FOR K40 (ENDOG) BODY MASS

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
5	197.00	161.00	179.000	25.456
10	164.00	153.00	158.500	7.778
20	148.00	158.00	153.000	7.071
26	165.00	150.00	157.500	10.607

AVERAGES FOR L.B.M. IMMERSION (KG)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
1	58.30	59.67	58.985	0.969
9	60.74	58.87	59.805	1.322
20	61.58	58.99	60.285	1.831
26	61.46	59.16	60.310	1.626

AVERAGES FOR LBM SKIN FOLDS (KG)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
9	64.61	63.17	63.890	1.018
20	65.74	64.04	64.890	1.202
26	65.75	64.84	65.295	0.643

AVERAGES FOR PERCENT BODY FAT (IMERS)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
1	18.60	19.10	18.850	0.354
9	16.90	17.80	17.350	0.636
20	16.90	19.40	18.150	1.768
26	16.90	19.80	18.350	2.051

AVERAGES FOR PERCENT BODY FAT (SK FL)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
9	11.60	12.00	11.800	0.283
20	11.40	12.50	11.950	0.778
26	11.30	12.10	11.700	0.566

AVERAGES FOR CIRCUM CALF (CM)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
9	34.90	34.80	34.850	0.071
20	34.60	35.40	35.000	0.566
26	35.10	35.70	35.400	0.424

AVERAGES FOR CIRCUM THIGH (CM)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
9	51.70	52.20	51.950	0.354
20	50.00	53.70	51.850	2.616
26	54.50	53.50	54.000	0.707

AVERAGES FOR CIRCUM UP ARM RELAX (CM)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
9	24.70	23.50	24.100	0.849
20	24.90	23.50	24.200	0.990
26	25.00	24.20	24.600	0.566

AVERAGES FOR CIRCUM UP ARM CONTR (CM)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
9	28.50	26.80	27.650	1.202
20	28.50	26.30	27.400	1.556
26	29.10	27.50	28.300	1.131

AVERAGES FOR CIRCUM CHEST (CM)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
9	86.50	89.80	88.150	2.333
20	85.30	90.00	87.650	3.323
26	86.70	88.50	87.600	1.273

AVERAGES FOR CIRCUM WAIST (CM)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
9	71.30	76.50	73.900	3.677
20	73.10	77.30	75.200	2.970
26	74.20	76.40	75.300	1.556

AVERAGES FOR STRENGTH HAND GRIP (KG)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
9	108.05	110.25	109.150	1.558
20	105.84	103.64	104.744	1.562
26	97.02	108.05	102.535	7.801

AVERAGES FOR STRENGTH KNEE EXT (LBS)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
9	200.00	175.00	187.500	17.688
20	170.00	146.67	158.333	16.501
26	183.33	205.00	194.166	15.322

AVERAGES FOR STRENGTH PLANT FL (LBS)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
9	220.00	245.00	232.500	17.690
20	230.00	286.67	258.335	40.066
26	240.00	270.00	255.000	21.222

AVERAGES FOR VITAL CAPACITY (LITERS)

INDIVIDUAL	10	12	MEAN	STD DEV
DAYS				
1	4.51	5.81	5.160	0.919
9	4.40	6.07	5.235	1.181
20	4.27	5.91	5.090	1.160
26	4.47	6.00	5.235	1.082

Part IV

DISCUSSION

Fluid Exchange

The evaporative water losses (EWL) reported for the ambulatory period are within the normal range of 1200 to 1500 ml for an ambient temperature near 80° F (Consolazio, Johnson, and Pecora, p.346, 1963). The value for daily insensible water loss (IWL) is approximately 1000 ml water for a 70 kg man (Elkington and Danowsky, p. 19, 1955; Weisburg, p. 47, 1962). When converted to a 24 hour period, the IWL values at night were very close to this value for both groups. The control group's IWL was very little different during night and day periods throughout bed rest. In addition, both periods were close to the night IWL recorded during the pre-bed rest period. Hence, night IWL proved to be an acceptable index for estimation of the IWL during periods of inactive recumbency.

The estimation of fluid requirements from night IWL and sweat rate during 30 min exercise bouts was successful. However, the daytime IWL for the exercise group was much lower during bed rest than the night IWL during the ambulatory period, while the sweat rate was much greater than anticipated. Hence, the increased sweat rate and lower than expected IWL averaged together were equal to the anticipated fluid requirement. The exercisers' night IWL during pre-bed rest and bed rest was the same, which limits the unexpected water exchange values to the day period. Since the control subjects did not change in day IWL between the two periods, it is assumed that the lower day IWL in the exercisers is due to the nature of sweat loss during the daily exercise bouts, i.e., the IWL was lowered between and after the bouts of work due to the increased sweat rate.

Since changes in the water output by extra renal routes were matched by changes in water intake in both groups utilized in this study, urinary outputs were approximately representative of water losses from the body. In previous studies of water exchange during bed rest (Deitrick, Whedon, and Shorr, 1948; Vogt *et al.*, 1965), water intake was variable, i.e., *ad libitum*. Hence, the urine volumes they reported were not necessarily representative of absolute changes occurring in renal water regulation. The estimation of water requirements in the present investigation was 60 ml high for the exercisers and 30 ml for the controls, with urinary output increases of 70 ml and 130 ml, respectively. The absolute urinary volumes on non-renal test days (relative to pre-bed rest ambulatory values) were increased by 10 ml in the exercisers and 100 ml in the controls.[1] Deitrick, Whedon, and Shorr(1948) reported a 235 ml daily average increase in urine production during immobilization, while fluid intake was decreased 18 ml. Vogt et al. (1965) reported an increased urinary volume of 350 ml in non-exercise conditions and a decrease in fluid intake of 550 ml, while in exercise conditions there was an increase of 300 ml in urinary output and a reduced fluid intake of 200 ml. It should be emphasized that the subjects utilized in both of these studies were active during the pre-bed rest period; hence, alterations in sweat rate during bed rest would have influenced the changes noted (i.e., since EWL was unknown, the decreased water intake at the onset of bed rest may not have been commensurate with the reduction in EWL). It is concluded that the diuresis of recumbency seen in this study is of smaller magnitude than that reported previously by some authors because of the adjustment of water intake according to changes in extra renal water excretion during bed rest. Other authors (Lamb and Stevens, 1965; Stevens and Lynch, 1965), have also reported only slightly elevated urine volumes, observing that the largest daily urine volume occurred on the first day of recumbency and was followed by an output only slightly elevated over pre-bed rest; this trend was also observed in the present study.

The body weights and urine volumes of the exercise subjects fluctuated during bed rest, with each showing proportionately opposite trends. When water loads were administered on renal test days, there was an apparent retention of water for the duration of the first day and a loss of "extra" urine during the next day, which resulted in an average body weight only slightly less than pre-bed rest baseline values. This rise and fall was related to each test day, and the observed weight on day 20 was not appreciably different from the pre-bed rest body weight. In contrast, with the exception of day 15, the control subjects lost "excess" water within 24 hours after administration of the water load. On day 15, serum osmolality reached the highest level observed in this group. By day 19, osmolality had decreased and the trend of urine volume and body weight indicated a steady loss of the water retained on day 15. It is concluded that the transient retention of water on days 15, 16, and 17 was due to an antidiuresis stimulated by an elevated body fluid tonicity.

The patterns of all water exchange that distinguished bed rest from ambulatory periods were apparent during the day, viz.: 1) the reduction of IWL in exercisers occurred only in "day" hours, as night IWL during pre-bed rest and bed rest was unchanged; 2) the increased urinary flow rates during bed rest were evident only in "day" periods of collection (a response seen in recumbency studies by Borst and de Vries (1950); and Sirota et al. (1950); 3) the diuresis associated with water loads was evident only in day urinary flow rates, and if some of the load was retained and excreted the next day, the night rates were nevertheless unchanged; 4) the antidiuresis during recovery was manifested only in day urinary flow rates, as night rates were unchanged or increased during this period. There is no apparent reason for the day pattern during bed rest, unless the water loss during recumbency is assumed to be an active metabolic process that is reduced during sleep. However, the fact that the antidiuresis during the day in the recovery period was not reflected in the night rates indicates that water retention occurs only during ambulation, or more specifically, in the upright posture.

The prevalence of a "day" pattern is complicated on the two renal test days during recovery in that the subjects were recumbent during the tests which began at 0700, while on other days of the recovery period, ambulatory activities began at 0700. Hence, the pattern of the 2½ hour urine production on the renal test days actually represents conditions following 10-12 hours of recumbency. Once the tests were concluded and the

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[1]The criterion for increased urinary volume was determined by the formula: (urinary volume bed rest - urinary volume pre-bed rest) - ([fluid intake bed rest - fluid intake pre-bed rest] - [EWL bed rest - EWL pre-bed rest]).

subjects became ambulatory, the diuresis ended abruptly, and in fact, both groups retained water throughout the remainder of the day, resulting in positive water balances on both renal test days. Therefore, during recovery there were two opposite extremes manifested: 1) the increased diuretic response to a water load in the recumbent position; and 2) an antidiuresis in the upright and ambulatory posture. Serum osmolality declined during recovery and was lower in both groups than in either of the two preceding periods. It is assumed that the water diuresis was produced by the absence of any postural effect and by the reduced serum osmolality. It appears that the orthostatic antidiuretic response overrides the lowered serum osmolality (the latter being an adequate stimulus to promote a diuresis only in recumbency). This contention is supported by the increased serum tonicity and water retention of the controls on day 15. Since the orthostatic response involves a reduction of the central blood flow and volume, such a response is in agreement with the hypothesis that blood volume is operant over tonicity (Gauer and Henry, 1963; Gauer, 1968). However, in the absence of any change of blood volume distribution during recumbency, tonicity would appear to be the regulating factor in both the bed rest and recovery periods.

During bed rest it was observed that the 2½ hour urinary output following the water load was only slightly larger in the controls (amounting to approximately 10 percent more of the load during the 2½ hour period) than the exercisers. Also, the controls lost more of the water load in the recovery period when the diuresis was interrupted by a 30 min bout of exercise than during the non-exercise bed rest period. Thus, these inter-group and intra-group comparisons indicate that the immediate effects of exercise do not result in increased water retention and hence, do not explain the exercisers' attenuated loss of body water during bed rest. The lack of water retention in supine exercise may be explained, however, by the absence of an increased antidiuretic hormone (ADH) output. Kozlowski et al. (1967) have shown that supine exercise causes no significant rise in serum ADH activity, although they showed a significantly increased ADH activity in upright exercise. They concluded that the upright posture was necessary for pooling of blood in the legs, which in turn stimulated the secretion of ADH. Rogge and Moore (1968) showed that the application of lower body negative pressure (LBNP) while in the supine position (which causes pooling of blood in the legs) increased ADH levels significantly. (The resemblance of LBNP and exercise effects during bed rest will be developed more completely in the section concerning renal function.) In the present investigation, it is postulated that although there may have been small immediate effects of exercise during bed rest, the major effect of the exercise regimen is shown by the lower 24 hour urine volume in the exercise group during bed rest and their ability to regain any water lost 24 hours after the resumption of ambulatory activities.

Water Balance

A description of the limitation of water balance calculations employed in the present study appears in Appendix V, Part II. The modified Peters-Passmore equation excluded the correction of changes in the non-water components of body composition. Although the error is small for periods of 24 hours, the error for a longer period of time (e.g., one week) is large, due to changes in fat, muscle, bone or intestinal residue, which cause a change in body weight. Using the modified formula, these changes would be interpreted as alterations in water balance. However, the method employed is adequate for delineating changes in routes of water exchange (as no cumulative error can occur), and for calculation of water balance on single days when large fluctuations occur, such as day 20 in the exercise group and day 22 in the control group. The values for average water balance in pre-bed rest show a negative balance in spite of other indications that normal balance had been attained (e.g., serum and urinary electrolytes and osmolality values on days 9 and 10 being equal to those on day 1). The discrepancy in the calculated water balance occurs as a result of a weight loss from day 1 to day 10 of approximately 0.4 kg, which is assumed to be due to reduction of intestinal bulk resulting from the low residue diet. Hence, such a change is calculated as loss of water, because fecal weights and food weights (although the latter was relatively constant) were not incorporated into the formula during this period.

The two groups showed increased body fat and decreased lean body mass (LBM) with bed rest, which would explain the fact that average water balance (as calculated by the method described) was not negative during bed rest. An increase in fat, which is only 10 percent water, would obscure a decrease in body water if only body weights were considered. The fact that the controls' body weight actually decreased, whereas a positive balance was recorded, can be explained by the various corrections of weight that are included in the calculation (e.g., those for fecal water, vomitus and blood losses). A negative water balance is substantiated by an increased urine volume despite an unchanged water intake relative to EWL, and a decreased LBM, thus indicating a loss of the lean body components, including water. The loss of water can only be indicated qualitatively, as none of these methods can be considered to represent quantitative values.

Body Fluid Volumes

Titrated water (T_2O) was employed as a measure of body water content. The intravenous method, which required the injection of 1 ml of T_2O was chosen in order to keep the volume of administered fluids in excess of daily requirements to a minimum. It was discovered, however, that such a small volume required unattainable accuracy in the measurement of the administered dose. The dilution of 1 ml by 40,000 ml of body water requires an accuracy of weight of 0.010 mgm for 10 percent accuracy. Although such accuracy is possible in weighing, other sources of error, such as evaporation between the times of weighing and administration, resulted in highly variable results. Agreement in multiple samples within one day was acceptable, but the reliability between any two days of measurement was not. For example, subject 8 had a measured total body water (TBW) loss of 7.0 L during bed rest, yet, there were no commensurate changes in body weight, urine production, or LBM to substantiate the loss of anywhere near this amount of water.

With one exception, the RISA method of determining blood and plasma volume (PV) proved to be a reliable technique. In three of six determinations, subject 1 had increased radioactivity about the areas of intravenous injections, indicating perivascular leakage after the injection of the solution. Because he was relatively large (80 kg) the inclusion of his other three measurements would have changed the trends shown in the averages of the other three subjects on the six days. Therefore, the values of this subject were eliminated from further analysis. The trends were considered to be reliable only if 3 out of 3 exercisers or if 3 out of 4 controls showed consistent changes within either group.

Numerous research workers have shown that the maximal depression of PV occurs after two to six days of recumbency and is not greatly changed in periods as long as 28 to 31 days Lamb and Stevens, 1965; Miller et al., 1965; Vogt et al., 1966; Vogt and Johnson, 1967a; Vogt et al., 1967b). A similar trend was noted in the present study, in that the average PV of controls decreased after 2 days, decreased still further after 5 days, but exhibited no further change during bed rest. It was also noted in these studies that the PV returned to pre-bed rest values after 3 to 7 days of recovery, which was observed in the present experiment, as well. Studies with exercise employed as an experimental variable during recumbency have shown no alteration in the course of PV contraction (Miller et al., 1965; Vogt et al., 1965). The application of cuffs to the legs in water immersion, lower body negative pressure (LBNP), and exercise on an ergometer in recumbency all serve to increase the volume of blood contained in the extremities, which may reverse the diuresis of recumbency by resembling the conditions of upright posture. Experiments utilizing LBNP have demonstrated that the PV was maintained by this procedure (Lamb and Stevens, 1965; Stevens et al., 1966). The application of cuffs to the extremities in water immersion studies has usually reversed the reduction of PV (Vogt, 1967c,d). In the present experiment, exercise subjects were observed to reverse an initial decrement in PV after 2 days of recumbency and return to pre-bed rest values at the end of the recumbency period.

Lamb and Stevens (1965) found a positive relationship between fluid balance and body weight and plasma volume during bed rest. It was previously pointed out that urine volumes and body weights in the present study were closely related in both groups, although urinary volume and PV show a relationship only during bed rest in the control subjects.

Therefore, it appears that PV contracts along with total body water losses in the immobile control subjects. However, the PV contraction appears to be completed very early in bed rest, whereas TBW is lost over a longer period of time.

Renal Function

The reproducibility of serial measurements of renal plasma flow (RPF), as detailed in Part III, was $\pm$ 10 percent (i.e., $\pm$ 30 ml/min), and the test-retest repeatability (i.e., between two days) was found to be $\pm$ 50 ml/min. This error is somewhat smaller than that reported by Chapman et al. (1948), who found RPF to be reproducible by $\pm$ 89 ml/min in duplicate trials. If three exercisers (subject 1 was eliminated from discussion of RPF for reasons mentioned in Part III) and three out of four controls showed the same response pattern, the change was considered representative of intra-group trends. On the basis of these criteria, the exercisers showed no changes throughout bed rest and recovery, as the fluctuations were all within the limits of measurement error. The controls' trend of RPF remained unchanged by the above criteria. The slowly increasing RPF during bed rest, as well as the elevated values during recovery, are considered representative of intra-group patterns.

To our knowledge, there have been no studies of the effects of prolonged bed rest on RPF. It has been shown that a change from upright to recumbent positions, and vice versa, causes an increase and decrease in RPF, respectively (Epstein et al., 1951). Although such an observation applies to the effect of the ambulatory period, it does not directly pertain to the present study, since all measurements were made following 10-12 hours of recumbency and were conducted in the horizontal position.

Renal regulation has been the subject of a great deal of study, although most of the work has been only indirectly related to RPF (Davis, 1962; Brown et al., 1964; Thurau, 1964; Tobian, 1967; Mills, 1968; Pearce, 1968; Perlmutt, 1968). These studies indicate that the endocrine and nervous systems are the two general systems related to RPF control, and each has been shown to have its sensory components. The stimulus for endocrine regulation has been hypothesized to be the changes in pulse pressure, blood pressure, blood volume, serum sodium concentration or tonicity of the body fluids in general, or sodium concentration or tonicity in the distal tubular filtrate. In addition, changes in blood volume or ECF volume may serve as stimuli to central nervous integration centers and are relayed to the kidney by the autonomic nervous system. The endocrine control category also includes the hypothesis that ADH is involved in renal hemodynamics, which may have some effect on peripheral vascular resistancy (Perlmutt, 1968), although at normal ranges of physiological concentration of ADH, this function is doubtful (Pitts, p. 37, 1963). The hormone renin, which is presumably produced by the juxta glomerular apparatus (JGA) may, indirectly or directly, effect RPF (Castenfors, 1967c). It has been postulated that changes in RPF represent changes in renin secretion by the JGA, which in turn catalizes the angiotensin system to stimulate the secretion of mineralocorticoids. In addition, sodium concentration in the plasma, or in the distal tubular filtrate, may serve specifically to regulate renin secretion.. Renin is thought to regulate renal blood flow either by changing total effective blood volume distribution or by changing the tone of the afferent arterioles, indicating that two mechanisms may be involved separately or in combination: 1) electrolyte regulation of renin; 2) renin regulation of electrolytes, primarily sodium and potassium (Davis, 1961; Castenfors, 1967a; Tobian, 1967).

The neurologic control of the kidney has been well documented (Castenfors, 1967c; Tobian, 1967; Pearce, 1968), and in addition, the sensory system for such control is thought to be related to changes in blood volume and in ECF volume (Gauer and Henry, 1963; Tobian, 1967). In the present study, the slowly diminishing blood volume (BV) did not serve to decrease RPF in the control subjects. However, the slowly changing BV is not analogous to the immediate effect of hypovolemic orthostatic responses which is assumed to be of neurologic origin. The latter response involves a transient alteration in the distribution of blood, the effect of which is a reduction in central blood volume and a transient reduction of RPF (Tobian, 1967). Exercise alone has been shown to reduce RPF, either in the upright (Chapman et al., 1948; White and Rolf, 1948) or recumbent positions (Castenfors, 1967a; Grimby, 1965). This response has been shown to be of nervous origin (Bozovic and Castenfors, 1967a; Castenfors, 1967b). Therefore, it seems that in immediate changes of blood, nervous control mediates the changes in RPF in concert with circulatory dynamics. However, the long term regulation of RPF in static conditions is unknown. Of the two possible control systems, endocrine and neurogenic, present evidence indicates that the kidney blood flow is primarily regulated by nervous input, although autoregulation by the renin-angiotensin system cannot be ruled out. It has been shown that even the JGA may have a nervous supply (Barajas, 1964), which, of course, emphasizes nervous rather than endocrine control of renal circulation.

The factors of renal regulation mentioned above resemble the mechanisms of cardiovascular regulation, in that there would appear to be components of autoregulation as well as nervous and endocrine control. The cardiovascular system has been the subject of great interest in bed rest and space flight studies, with deconditioning of the cardiac response to orthostatic stimuli being observed in both conditions. (McCally and Lawton, 1963). Normally, approximately one to two weeks is necessary for return to normal. Since RPF represents an integral part of the cardiovascular system, it may be postulated as undergoing the same type of deconditioning during situations where no stimuli to the effector organs are permitted. Such a deconditioning could affect the kidney during resting states, but such an effect is not implied by the analogy to the tilt table cardiac response. However, inasmuch as the stimulus in orthostatic hypotension is a redistribution of the central blood volume, the response of the kidney to exercise in the present investigation can be compared to the tilt table response (having in common an increased volume of blood contained in the extremities). This will be discussed later in the section concerning the physiological response to exercise.

Glomerular filtration rate (GFR) was shown in Part III to be a repeatable measurement over 24 hour periods during pre-bed rest. This is in agreement with Doolan et al. (1962) who found 24 hour clearances to be reliable upon repeat measurements. In addition, all general trends of the intra-group response were represented by three-fourths of the subjects consistently.

The relation of GFR to tubular function is presently the subject of intense investigation. Recent reviews (Leysac, 1967; Berliner, 1968; Rector et al., 1964) have concluded that the nephrons can act independently of GFR, while earlier studies had shown convincingly that tubular function was greatly influenced by GFR (Davis, 1961). Inasmuch as electrolyte metabolism represents the end product of renal function, further development of this point will be delayed for the electrolyte balance discussion.

Our observation of a decreased GFR at night agrees with the findings of others (Borst and de Vries, 1950; Sirota et al., 1950), although there was a greater reduction in the present study. The reduction of GFR and of urine flow are probably an indication of decreased renal metabolism, since in addition, electrolyte excretion has been shown to decrease at night (Sirota et al., 1950; Vogt et al., 1965).

Urinary Electrolytes[1]

Of the three basic questions raised in the present investigation, the primary attention has been centered on alterations of metabolism and water exchange. The analysis of water exchange has shown that there was an increased rate of urine production. The exact nature of the negative water balance can be best characterized by solute exchange and solute-free water exchange. Therefore, the question arises as to whether the regulation of TBW comes through osmotic concentration or through volume of the ECF.

Previous studies of the diuresis of recumbency have shown that there is both an increased osmotic and free water clearance in recumbency (Surtshin and White, 1956; Hulet and Smith, 1961; Streeten and Speller, 1966). Each of these investigations demonstrated

[1]Only osmolality and sodium are discussed in this section; other urinary constituents will be discussed in the following section.

that sodium was the main osmotically active urinary component that was increased, and that the free water diuresis was secondary to the increased osmotic clearance of sodium. These studies lasted for less than 24 hours, with clearances measured over periods of less than several hours. Osmotic and free water clearances in the present investigation were calculated for 24 hour periods, with a 24 hour collection of urine representing the average osmolality (Uosm).[2] While the subjects were recumbent, however, only one plasma sample was collected for determination of plasma osmolality (Posm) in the morning. During bed rest this sample was approximately representative of one 24 hour Posm. However, during pre- and post-bed rest periods, when there were alternating periods of ambulation and recumbency, the sample Posm did not represent the average 24 hour osmolality, inasmuch as it has been shown that Posm changes as much as 10 mOsm/L from the recumbent to the erect posture (Surtshin and White, 1956; Streeten and Speller, 1966). For this reason, another method was sought for determination of 24 hour osmotic and free water clearances. Some authors have used estimated values in the calculation of Cosm and CH2O when average Posm is unknown (Hunt, 1967; McCally and Bernard, 1968). Referring to the formulas for these two parameters (see Part III), the inclusion of a constant Posm results in a value identical to the calculated solute output, or VUosm. The value for CH2O becomes merely an expression of the relationship of VUosm with urine volume. By comparing Uosm and VUosm, an estimate of Cosm and CH2O can be made without the use of a fixed Posm. The calculated clearances during bed rest are assumed to be accurate, and comparison of Cosm and CH2O with the pattern of osmotic output and osmolality (figure 3.3) show similar trends.

Both methods of calculation of osmotic and free water excretion showed a mixed diuresis during bed rest. The exercise subjects demonstrated similar decreasing osmotic and free water clearances in two of the four days measured, and a slightly larger osmotic than free water clearance on the other two days. Therefore, the total water loss of the exercisers is assumed to be the result of a near isotonic body fluid contraction. The controls showed an alteration of trends in free water and osmotic clearance on day 15 (it will be recalled that day 15 was previously shown to be the only day on which there was a retention of water). At the onset of bed rest, osmotic and free water clearances were higher than pre-bed rest levels, whereas after day 15, both clearances were substantially decreased in relationship to baseline levels. CH2O was elevated in the controls, relative to day 9 levels, to a greater extent than Cosm throughout bed rest, thus indicating a slight hypertonic contraction (with a controlled water intake, no dilution of body fluids could have occurred as a result of an increased input, and water exchange data did not indicate that such a situation occurred). The relatively unchanged osmolality in both groups during bed rest in contrast to a changing VUosm, compares favorably with the observations of Hulet and Smith (1961) in short term recumbency studies.

The comparison of sodium clearances shows that the pattern of VUosm is identical to VUna/Pna (sodium clearance) in both groups. In addition, the changes in Una (urinary sodium concentration) were relatively slight (similar to Uosm), whereas the changes in VUna (excretion rate, μEq/min) were distinctly changed in a pattern similar to VUosm. This would indicate that the solute excretion may have been passively followed by free water, and was largely associated with sodium excretion. This contention has been summarized by Hulet and Smith (1961) as, the "Primacy of Increased Sodium Excretion".

The data from the recovery period in both groups showed a very large osmotic and sodium retention, although urinary osmolality was only slightly changed, i.e., there was an isotonic expansion and an obligatorily decreased free water excretion, which was the reverse of the trend during bed rest. Hence, during recovery, sodium was the primary solute involved in water retention. The controls showed a slightly larger osmotic retention than water retention, which was also similar to the situation observed during bed rest, i.e., a predominantly solute, rather than free water pattern.

The discussion immediately preceding may serve to explain that the diuresis-antidiuresis and natriuresis-antinatriuresis mechanisms acted concomitantly throughout the

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[2] In the present study, no distinction has been made between osmolality and osmolarity.

two experimental periods. If only ADH were active in promoting the fluid retention, urinary concentrations would be increased, and likewise, if only sodium retention mechanisms controlled the response, urinary concentrations would be decreased. By administering a potent mineralocorticoid after four days of recumbency for a period of two days, Stevens and Lynch (1965) have provided evidence that sodium alone may mediate the loss of body water. They reported a complete reversal of the loss of water and salt during the final two days of recumbency. However, serum sodium was not measured, and urinary sodium concentration was not reported; hence, it is not possible to state whether a hypertonic expansion (due to sodium retention in excess of water) or an isotonic expansion occurred.

Electrolyte Metabolism

Previously, it has been stated that the exercisers in the present investigation underwent an isotonic contraction, and the controls a slight hypertonic contraction of body fluids. With the absence of any large gain or loss of free water, the serum electrolyte concentrations are representative of the total ECF electrolyte content. The change in the ECF volume over a period of several days would not result in any appreciable error in the use of the fixed volumes of 13.5 L and 13.2 L for the exercise and control groups, respectively. A previous 10 day bed rest study showed a loss of 1.1 L in four days and 2.2 L in 10 days (Vogt and Johnson, 1967a). However, the use of the estimated ECF volume in the present study is restricted to comparisons over short periods of time.

The calculation of sodium and chloride balance by both methods showed that the corrected day 9 balances were higher than the balances calculated by the more accurate input-output method. The latter method does not include the sodium and chloride lost in the sweat, and due to this omission, the calculations for both groups in pre-bed rest show positive balances. The amount of sodium and chloride in sweat varies by 18-97 mEq/L (mean of 45), although values as low as 6 mEq/L have been recorded in heat adapted subjects (Robinson and Robinson, 1954). Average excretion during pre-bed rest was 0.36 L of sweat; hence, the amount of sodium and chloride lost would be approximately 15 mEq, which in both groups, is approximately equal to the positive balance calculated from urinary input-output data. During bed rest, the controls had no active perspiration of consequence, while the exercisers excreted approximately 0.35 L of sweat in each of their exercise bouts. The excretion of salt is said to be adaptive over a period of two to five days, and can decrease from approximately 40 mEq/L to 10 mEq/L within this period. In addition, various other factors, such as low environmental temperature, short periods of sweating, small volumes of sweat, and negative sodium-chloride balance, cause lower concentrations in sweat (Robinson and Robinson, 1954). With these considerations in mind, the average amount of sodium and chloride excreted over the nine days of bed rest was estimated to be 10 mEq/L or 7 mEq/day. For the four days used in calculating the cumulative balance, this represents 28 mEq loss not accounted for, or a balance of -122 mEq in the exercise group on day 18. The amount of potassium lost in the sweat is negligible at the sweat rates in the present experiment.

An additional consideration on renal test days was the ingestion of 800 ml of water 30 min prior to the basal blood sample. The time lapse was precise and usually varied by no more than two to five minutes. In a previous study (Baldes and Smirk, 1934), it was shown that water uptake begins approximately ½ hour after ingestion of a water load, and that maximum uptake occurs at 1 hour post administration. The dilution of serum in the present experiment by the preliminary uptake at 30 min was certain to have occurred. However, any such dilution was consistent throughout the experiment, as time of administration and volume of the load were carefully controlled. It is realized that the sodium and chloride from the blood equilibrate with distilled water in the gastroenteric system; however, this was probably negligible at the time when samples were taken. Therefore, the relative comparison of the serum values is not though to be affected by this procedure, although serum values may have been consistently lowered to a slight degree.

After two days of bed rest, the ECF sodium of the exercise group was increased by 40 mEq and urinary excretion by 30 mEq/day. In addition, dietary input was reduced by 50 mEq/day. Therefore, to increase blood levels in the absence of hemo-concentration, a total of 120 mEq must have been added to the ECF. An additional 7 mEq or more, due to sodium loss in the sweat, results in a total sodium loss of 127 mEq. An identical situation existed in the control subjects on day 12, in that sodium in the ECF was increased by 50 mEq and input-output balance was -100 mEq. It follows that approximately 150 mEq of sodium was added to the ECF and subsequently lost via the kidney. Lynch et al. (1967), in a study of sodium balance during prolonged recumbency, showed a loss of 137 mEq sodium over a total of 28 days. The fact that the total sodium lost over 4 days in the present study is close to the amount lost over 28 days, and that the negative balance diminished throughout bed rest, suggests that the loss of sodium is nearly complete after a few days, and that longer periods of bed rest may not increase the negative balance. There have been other reports of increased sodium excretion within the first 24 to 48 hours of bed rest, followed by a diminishing urinary sodium output. In these studies, serum sodium was observed to be relatively unchanged after one week (Birkhead et al., 1963; Stevens and Lynch, 1965; Vogt et al., 1965; Lynch et al., 1967). In order to account for the negative balances observed in the present study, it is suggested that sodium is released from a reserve outside the ECF. The largest sodium reserve in the body is cancellous bone, which when combined with several other reserves of the body, amounts to approximately 2900 mEq of exchangable sodium in a 70 kg man (Edelman and Leibman, 1959). It is tentatively hypothesized that the bone reserves and other sources of exchangable sodium released the sodium that was added to the ECF. Studies with sodium deficient diets in man have shown that sodium can be mobilized in periods as short as 48 hours (Jagger et al., 1963). In studies conducted on acute acidotic dogs, 14.9 mEq/kg of sodium was mobilized in six hours (Nichols and Nichols, 1956). Based on results in this investigation, it seems reasonable to assume that utilization of sodium reserves could have accounted for the negative sodium balance. After five days of recumbency, the exercise group had changed to a positive balance and had decreased the ECF sodium. A positive balance and a decrement in ECF levels indicates that there was no further release of sodium from the reserves. In contrast, the controls showed a slightly increased serum sodium and a negative balance, which indicates a continued sodium release, although of lesser magnitude than on day 12. There was a slow decline of ECF sodium content on the remaining days of bed rest that was equal to the loss of sodium in the urine. Hence, the additional negative balance in the controls likely occurred at the expense of the ECF. As previously mentioned, there was a slight hypertonic concentration of body fluids in the controls, which could have shown the ECF sodium content to be deceptively high, i.e., ECF sodium was decreased more than is apparent from the decrease in the estimated values.

The cumulative four day sodium balances demonstrate additional evidence that there was some degree of exchange between the water and non-water compartments during bed rest. Sodium was in negative balance by 94 mEq in the exercisers, and 140 mEq in the controls. With the average concentrations of serum sodium measured in this experiment, this represents a loss of 0.7 L of ECF in the exercisers and approximately 1 L in the controls. However, on these days, urine flow was increased over pre-bed rest values by an average of 10 ml in exercisers and 100 ml in controls,[3] which indicates further that, unless a very large concentration effect took place, nearly all of the negative balance was due to the addition of sodium from outside the ECF.

Following bed rest, there was again an exchange of sodium which was not accountable by the methods employed. In spite of a lack of hemo-dilution, and in the presence of a marked anti-natriuresis, ECF levels were further reduced after one day of recovery in the case of the controls, and after six days in the exercisers. Although exact balance data

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[3]The increased urine volumes compared with pre-bed rest values were 70 ml in the exercisers and 130 ml in the controls; however, 60 ml and 30 ml of water in excess of water requirements was given to exercisers and controls, respectively, during bed rest, which resulted in an actual increase in urine volume by 10 ml in the exercisers and 100 ml in the controls.

is not available, the subjects' daily logs did not show a decreased electrolyte intake in the diets during the recovery period. The only explanation for the discrepancy between a sodium retention and decreased ECF levels is a return of sodium of the reserves. The studies of recovery following sodium depletion by Jaggar et al. (1963), supports this contention.

Comparison of the two groups shows that the exercise group did not lose sodium to the degree observed in the controls. With the addition of the estimated loss of sodium in the sweat, there was still a 20 to 30 mEq greater loss in the controls. During recovery, the controls may have reflected a greater loss by a marked antinatriuresis. This is in contrast to the retention of water during recovery, in which the exercisers showed a greater ability to regain the water lost during the 48 hours. It should be noted that the antinatriuresis of the controls may have been deceptive, in that the controls increased EWL by 0.68 L during recovery, whereas the exercisers, who had previously been excreting 0.70 L sweat daily during bed rest, increased EWL by 0.19 L. Robinson and Robinson (1954) felt that with increased sweating, preceded by a long period of minimal sweat excretion, there was a proportionantely greater loss of sodium. Therefore, sodium may not have been as effectively returned to reserves in controls, as is suggested by the decreased urinary sodium output in the first 16 hours.

Potassium balance was calculated by a single method, in which day 9 was assumed to be representative of normal renal function. Comparison of this method with the input-output methods in sodium and chloride balances showed the former to give larger negative balances, although the relative difference in balances between the exerciser and control groups was similar. Therefore, potassium balance cannot be conclusively related to ECF levels, although largely negative balances are assumed to be reliable indications of metabolic trends. Lynch et al. (1967) have shown that there is little change in potassium lost in the stools during bed rest (a decrease of 38 mEq over 28 days was observed). It would appear, then, that this route of potassium loss can be considered constant, which would leave only changes in renal excretion to account for potassium balances.

Losses of potassium on the first day of recumbency were substantially smaller than sodium. As the bed rest period progressed, there was a continued increment of potassium excretion in contrast to sodium, in which the largest excretion and negative balance occurred on day 11. In a 14 day bed rest study, Vogt et al.(1965) observed that the increased loss of potassium was reversed after 8 days of recumbency in the non-exercising subjects. In the present study, as bed rest progressed, potassium losses increased without a concomitant decrease of ECF levels, which indicates a release of potassium from reserves.

Cancellous bone and intracellular potassium are the two sources of potassium available for exchange with the ECF. In a study of sodium depletion, Lobeck and Forbes (1958) have shown that although potassium is mobilized from cancellous bone, the amount available for exchange is very small. However, it has been stated that nearly all of the total body potassium contained intracellularly is available for exchange (Moore et al., 1956; Edelman and Leibman,1959). Although the source of potassium can not be determined in the present study, the presence of a negative potassium balance is qualitatively shown by the negative urinary balance, and in addition, by total body potassium counts. The amounts lost during bed rest,as determined by K_{40} counts, were 80 mEq in the exercisers and 170 mEq in the controls. These values compare qualitatively with the urinary balances of -57 mEq and -152 mEq in the exercisers and controls, respectively. It should be recalled that balance calculations in the latter values were higher when compared with input-output calculations, and that these cumulative balances are totals for only 4 of the 9 days of bed rest, whereas K_{40} counts represented a cumulative balance for the entire 9 days of bed rest.

Unlike sodium excretion following bed rest, potassium excretion did not reflect the preceding negative balance by urinary retention of this cation but, instead, remained unchanged from bed rest values. These trends may be related to the magnitude of sodium imbalance and the mechanism of sodium retention, which can be determined by sodium-potassium ratios.

The increased urinary sodium-potassium ratios on day 11 are in agreement with those observed in previous short term recumbency studies (Thomas, 1957; Steinmetz and Eisinger, 1966), as well as those in a study of longer duration (Vogt *et al*., 1965). This high ratio has been attributed to aldosterone inhibition at the onset of recumbency (Gowenlock *et al*., 1959). However, in the present study, ratios were reduced following day 11, and remained low throughout bed rest, while aldosterone levels were unchanged or reduced in 2 out of 3 exercisers or controls, respectively. It has been demonstrated that the administration of a potent mineralocorticoid reverses the water loss and sodium loss after 6 days of recumbency (Stevens and Lynch, 1965). In the present study, the sodium-potassium ratios were not related to either aldosterone excretion or sodium balance (the latter being clearly negative in both groups), which suggests that a decreased sodium-potassium exchange may not be the only means by which sodium was lost; or conversely, the administration of an aldosterone-like drug may not reverse all of the causes of the natriuresis. The observation of a slowly decreasing ratio after a brief initial increase, has been reported in a similar prolonged recumbency study (Vogt *et al*., 1965).

It has been mentioned previously that GFR may not be as important a factor in the control of sodium excretion as it was once thought. In the present study, comparison of the filtered load and the clearances of sodium during bed rest showed that GFR has no relationship to sodium balance. The controls had a decreased GFR on day 11 and were in a larger negative balance on that day than at any other time during bed rest. The filtered load showed no consistent relationship to the clearances in either group. Therefore, it appears that a factor other than GFR regulates sodium excretion during bed rest. However, there was a distinct relationship in both groups following bed rest, as 24 hour GFR was uniformly decreased on the first and third days of ambulation. The percent sodium reabsorbed on day 9 was calculated as 99.0 percent in both groups, while on day 20, it was 99.5 percent and 99.6 percent in the exercisers and controls, respectively. The results for day 20 reflects the trend of antinatriuresis observed on that day and also indicates the contribution of the reduced GFR in establishing the antinatriuresis.

From analysis of pertinent results of the present study, it is concluded that the two criteria for renal electrolyte metabolism, sodium-potassium ratios and the percent of the filtered load reabsorbed (fractional reabsorption), do not explain the negative balances of sodium and potassium during bed rest and, in fact, are clearly not related to the renal metabolism of these electrolytes. However, following bed rest, these two factors show a pattern consistent with the observed antinatriuresis, i.e., a lowered ratio and an increased sodium reabsorption.

The similarity in the trends of urinary excretion of chloride to that of sodium has been mentioned previously. This similarity was observed in both groups during bed rest and recovery, with both balances and clearances demonstrating similar patterns. However, this was not the case with ECF levels of chloride, as on day 12, they were decreased 58 mEq, whereas sodium was increased by 40 mEq. In addition, the control subjects differed from the exercisers, in that the amount of chloride lost was much larger than their sodium loss. Serum chloride levels revealed their greatest depression in both groups on day 11, but did not decrease further, whereas a negative input-output balance continued throughout bed rest. There was no concentration effect of any consequence in the ECF among the exercisers, who developed a negative balance of 131 mEq over the 4 days measured. ECF levels were decreased by 50 mEq during this period, resulting in 81 mEq unaccounted for by this method. In the control group, 271 mEq was lost in the urine, while ECF levels were 24 mEq lower, thus 247 mEq are unaccounted for. However, there may have been a larger amount lost in the ECF than is shown by this method. This would yield a value of less than the 247 mEq mentioned above due to some concentration of the ECF by loss of free water in excess of solute in the urine. Similar losses in chloride have been reported in a recent bed rest study (Lynch *et al*., 1967). These authors calculated chloride balance during bed rest by comparison with pre-bed rest values and found a total negative balance of 329 mEq during 28 days of bed rest. In the present study, the total balance for the controls (calculated in the same manner) during 4 of the 9 days of bed rest, was 459 mEq. As with sodium losses, it is suggested that there is a maximal chloride loss which occurs within several days after initiation of bed rest. However, due to the slower reduction of the negative balance thereafter, chloride losses are greater.

The bone reservoirs have very little chloride available for exchange, and the amount of total body chloride outside the ECF is less than 30 percent. Consequently, the total amount available from any source of exchangable chloride is only about 1000 mEq, which is thought to be totally exchangable (Edelman and Leibman, 1959). However, in most cases, the exchange of chloride involves its replacement with another anion. Bicarbonate can serve this function if it is elevated in the serum. In the present study, approximately 50-80 mEq of bicarbonate was estimated as the amount necessary to replace the chloride lost. However, it was observed that the replacement of chloride by bicarbonate in the ECF was insufficient in both groups to account for the balances observed, i.e., chloride was obtained from a source outside the ECF.

Titratable acidity was depressed in the controls throughout bed rest, an observation reported by others in short recumbency studies (Thomas 1957; Steinmetz and Esinger, 1966). However, in these studies, it was also shown that titratable acidity increased when erect posture was resumed, whereas in the present study, hydrion excretion of the controls was depressed during recovery, as well. The reduced titratable acidity during bed rest may be evidence that bicarbonate levels were compensatorily increased in response to a retention of hydrogen ion, although it also indicates that bicarbonate levels were not increased as a result of renal mechanisms. In addition, the lower hydrion output could be a reflection of reduced metabolic output, or increased organic acid (ash) input in the diet, in which case, there would be no correlation between the lower titratable acidity and increased bicarbonate levels.

Respiratory Metabolism

The basal oxygen consumption results of the present study are in general agreement with those of previous studies. Cuthbertson (1929) first noted a slight but steady diminution in basal oxygen consumption with bed rest. Deitrick, Whedon, and Shorr (1948) noted a mean decline of 6.9 percent in young men subjected to 6 to 7 weeks of bed rest, while Taylor et al. (1949) observed a mean diminution of 8.8 percent after 21 to 28 days of bed rest. Birkhead et al. (1963) found similar results in their subjects after 42 days of bed rest. Brannon, Rockwood, and Potts (1963), however, found no significant difference (no values given) in the BMR of 30 subjects assigned to varying degrees of horizontal physical activity during 60 days of bed rest. In the present study, the controls showed a decrease of approximately 10 percent, while the exercise group also demonstrated a general downward trend, but of less magnitude.

McCally and Lawton (1963) feel that there is a clearcut relationship between metabolism and gravity, citing the increase observed in metabolism on passive standing. They presume this arises from gravity stimulation of proprioceptors in muscles and joints with increased anti-gravity or extensor muscle tonus. It is not known whether any particular clinical significance (other than its possible indication of muscle atrophy) has been attached to the generally observed diminution of basal oxygen consumption with bed rest.

Close examination of the basal respiratory metabolism results in the present study reveals that there were no differences between the exercisers and controls in their pulmonary ventilation and respiratory rate pattern of response during bed rest. However, while the exercisers demonstrated no clear pattern in percent of true oxygen and respiratory quotient (RQ), the controls showed a greater than 10 percent decline in the former and a clear rise in the latter. Cuthbertson (1929) and Birkhead et al. (1963) have previously noted a rise in the basal RQ with bed rest, with the latter observing a return to pre-bed rest values in a three week recovery period. In the present study, a return toward the pre-bed rest RQ during the 7 day recovery period was also noted in the control group. This would appear to indicate that bed rest results in a slight hyperventilation that is not reflected in increased ventilation, but in decreased respiratory efficiency, i.e., lower true oxygen and higher RQ (the diet was of similar composition before, during, and after bed rest), with the end result being a diminution in basal oxygen consumption. The clinical significance (if any) of these observations and the mechanisms initiating them are not readily apparent. It is clear that such a small reduction in basal oxygen consumption as was observed in the present study is of little consequence in comparison to the reserve available for accomplishing heavy physical activity.

The higher respiratory metabolism and heart rate values observed in our subjects during the pre- and post-bed rest evening metabolisms merely reflect the general increase in metabolism with normal, ambulatory activity. Bed rest had no apparent effect upon the evening respiratory metabolisms that was not reflected in the basal metabolisms taken during the recovery period.

Both the exercise and control groups showed a stable pre-bed rest basal heart rate, with the former varying only slightly about this value throughout bed rest and recovery. Hence, the exercisers followed a trend similar to that observed by Brannon, Rockwood, and Potts (1963) and Birkhead _et al._, (1964), while on the other hand, the controls showed a general decline during bed rest, followed by an immediate rebound during recovery to higher than pre-bed rest levels. The latter finding is in direct contrast to previous observations of basal heart rate during bed rest without physical activity (Deitrick, Whedon, and Shorr, 1948; Taylor _et al._, 1949). Miller _et al._ (1964a) have also observed a rise in resting heart rate (there is some question as to whether they were taken under basal conditions) after two weeks bed rest, with similar observations noted in a group undergoing in-bed exercises. In a later study, Miller, Johnson, and Lamb (1964b) observed an increase in resting heart rate from 58 to 71 beats/min after four weeks of bed rest with no physical activity. The same workers (1965) subjected six young men to a modified horizontal bike ergometer exercise routine of 1 hour/day during 4 weeks of bed rest and observed an increase in resting heart rate from 74.8 to 90 beats/min.

While it is well appreciated that the heart rate changes in response to a variety of stimuli, both psychic and physical, it is well known that physical training produces bradycardia. Raab _et al._ (1960) have emphasized that individuals during bed rest and physical inactivity tend to develop a rapid resting heart rate with an inefficient myocardium due to the storage of catecholamine products within the myocardial cell. These workers feel that the catecholamines decrease the myocardial cell's ability to utilize oxygen, increase myocardial irritability, and predispose the heart to arrhythmias. The exact metabolic mechanisms whereby disuse produces a shift toward adrenergic preponderance, however, is unknown, since information is lacking regarding the synthesis, release, rate of turnover, and tissue levels of catecholamines in relation to level of training or use. Logically, then, one would expect non-exercising bed rest subjects to show an increase in basal heart rate, while those who exercise during bed rest might be expected to offset this tendency. The latter instance was observed in the present study, while the exact opposite was seen in the former. Other than a shorter bed rest period than utilized in other studies, no readily apparent reason can be advanced for this contraindication.

<u>Anthropometric Data</u>

Changes in body composition can occur in a variety of ways according to various effects. For example, loss of weight during caloric restriction involves losses of variable proportions of fat, of ECF, and of cellular material, which includes protein, water, and minerals (Grande, p. 914, 1964). The percentage composition of the tissue mass change with weight gain, according to various conditions have been given as follows by Keys (p. 25, 1955):

	Fat	Cells	ECF
Gluttony alone	66	20	14
Gluttony plus indolence	109	- 20	11
Physical training	- 38	120	18

A definite attempt was made in the present study to insure an adequate, but not overly abundant caloric supply during pre-bed rest and for the two bed rest conditions (exercise and non-exercise). The caloric content of the diet during pre-bed rest for a 70 kg subject was 3450 Cal, which was reduced to 2850 Cal for the 70 kg exerciser and 2450 Cal for the 70 kg non-exercising control. Taylor _et al._ (1949) observed no significant change in body weight with a similar pattern of caloric change for non-exercising bed rest subjects during a period of 3 to 4 weeks. Deitrick, Whedon and Shorr (1948) did not reduce the caloric value of the diet of their subjects during 6 to 7 weeks of bed rest, who nevertheless maintained body weight. They suggested that the weight constancy of their subjects was probably the result of the simultaneous loss of muscle protoplasm and storage of fat or carbohydrate. While no gross changes in body composition would be expected over a shorter time under the conditions previously mentioned in the present investigation, close analysis of several parameters indicates a measurable change in the body compositoin of both groups. It was observed that the control group lost over twice as much K_{40} as the exercisers, although any significance ascribed to the relatively small changes observed might well be accounted for by summation of possible limitations in precision and accuracy of the measurement technique. However, the data did indicate positively that no serious loss of potassium occurred in either group.

Credence to an actual loss of potassium in both groups and thus, in lean body mass (LBM) is given by the water immersion results in the present study. The controls were observed to lose almost three times as much LBM as the exercisers. Since the body density via immersion was lower in both groups, each gained some fat as computed by the formula of Brozek et al. (1963). The efficacy of prediction of fat change by skinfolds a' la Pascale (1956), which showed a slight decline in both groups, is open to question. While skinfolds have established, but somewhat limited validity in predicting body density (and hence, total body fat) in a cross-sectional study of a population, no study has sought to ascertain the effects of alteration in body composition due to changes in physical activity on their effectiveness of prediction.

The loss of LBM in both the non-exercising controls (to a greater extent) and the exercisers in the present study is substantiated indirectly. During bed rest, the subjects demonstrated no change in creatinine excretion from pre-bed rest values, even though their muscular activity decreased. Thus, with a constant excretion level during a period of decreased synthesis, increased muscle creatinine loss relative to pre-bed rest levels is suggested. In recovery, one would expect synthesis levels to return to normal. However, the observed decreased excretion tends to indicate a restitution of the muscle creatinine loss. It should also be noted that the controls showed a larger increase in urine potassium loss during bed rest than the exercisers of approximately the same magnitude of difference as observed in the K_{40} results. The reserves of potassium are located primarily (almost totally) in the muscle cells, and since potassium is not synthesized, what goes out of the cell is distinctly representative of cellular decrease.

The results of Birkhead et al. (1963) indicate that their subjects lost fat during bed rest, a finding in direct contrast to our water immersion results. It should be pointed out that they used the method of Behnke (1961), utilizing skeletal circumferences and diameters that yield no qualitative estimate of change in loss of mass expected during prolonged bed rest, i.e., whether the mass is fat or muscle. Hence, other than by estimates through body weight and circumferences measures, no prior study has dealt with changes in gross body composition during bed rest. Within the limits of our measurement techniques, it would appear that muscle mass is lost in a period of recumbency of nine days, although the small gain or loss in fat on a reasonably isocaloric diet can not be accurately assessed subcutaneously.

Deitrick, Whedon, and Shorr (1948) observed a decrease of about 2 percent in upper arm and forearm girth, 3.9 percent in thigh girth and 5.9 percent in calf circumference. Since their subjects were immobilized in bivalve plaster casts, it is likely that an appreciable amount of muscle atrophy took place especially in the lower limbs, during the 6-7 weeks of bed rest. In the recovery period, five to six weeks was required for the lower limbs to return to their original circumference. Birkhead et al. (1963) observed steady decreases in upper arm, thigh and calf girths during bed rest, amounting to approximately 4 percent at the end of six weeks. Less than half of the loss in limb girths had been regained after 18 days of reconditioning activity. Brannon, Rockwood, and Potts (1963) observed noticeable decreases in limb circumferences beginning in the second and third weeks of bed rest. Subjects who performed in-bed exercises during the full 60 days of bed rest did not develop upper arm girth losses (as was noted in a non-exercising control group), and incurred much smaller losses in lower limb girths than the control group. In the present study, the trend of our results appear to be in agreement with those of previous studies, inasmuch as the exercisers did not incur any significant girth reductions, while the controls lost a noticeable amount only in the thigh.

Measurable losses in muscle strength after several weeks bed rest have been noted in the lower extremities (Deitrick, Shedon, and Shorr, 1948), in the back (Taylor et al., 1949), in the upper arms (Birkhead et al., 1963), and in both the upper and lower extremities (Brannon, Rockwood, and Potts, 1963). No loss in grip strength was observed in any of these studies. In subjects performing in-bed exercises for 60 days, Brannon and his colleagues observed no noticeable loss of strength in the arms, and lesser amounts than the non-exercisers in the lower extremities. In the present study, the strength results in the exercise group appear to follow established trends of previous studies, in that no significant gain in grip or knee extension strength was observed. No readily apparent reason for the rather significant gain in grip strength by the controls can be advanced. The relatively large increment in plantar flexion strength observed in both groups throughout the experiment suggests a "learning" effect rather than an actual gain in strength.

Previous studies have shown no appreciable change in vital capacity (Dietrick, Whedon, and Shorr, 1948, and Birkhead et al., 1963). In the present study the vital capacity of the exercise group did not change appreciably throughout the experiment, while the control group's vital capacity dropped about 4 percent during bed rest, with a subsequent regaining of one-half this amount during the recovery period. Hence, it would appear that the respiratory stress of twice daily bicycle ergometer exercise is sufficient to prevent any slight decline in vital capacity that might arise with prolonged bed rest.

Residual lung volume was measured only once (at the end of the experiment) and revealed a significant difference between the exercisers and the controls. Brozek (1960) has observed a fairly close relationship between residual lung volume and vital capacity; hence, the distinct difference in residual lung volumes between the two groups was unexpected in view of their nearly similar post-bed rest vital capacities.

Physiological Response to Exercise

The depression of renal plasma flow (RPF) during exercise is a well known phenomenon that has been shown to vary proportionately with the amount and intensity of work (Chapman et al., 1948; Grimby, 1965). The latter also observed a significant correlation between heart rate and RPF; when heart rates were approximately 135 beats/min at the end of 45 min exercise in the supine position, the RPF was depressed to 73 percent of resting. These values are very close to those observed in the present study, in which heart rates of approximately 135 beats/min were recorded with RPF depressed to 67-72 percent of resting in the exercise subjects. The values of Castenfors (1967a) are very close to those above, with a 65 percent reduction of RPF and a heart rate of 150 after 30 min of exercise. The workload in this experiment was 729 kpm/min, compared to the workload of 806 kpm/min in the present study.

The exercise subjects did not demonstrate any change in the response to exercise, which supports the assumption that there was no change in renal hemodynamics throughout bed rest and recovery in this group. The control group, conversely, showed a different response to exercise immediately after bed rest, in that, after 16 hours of ambulation, they had a depression of RPF 15 percent greater than on day 10. After 6 days of ambulation, their response to exercise was similar to that observed on day 10. In spite of a depression of 62 percent of resting values, the RPF during exercise on day 20 was 556 ml/min, which is still higher than the flow on day 10 of 446 ml/min. The lack of further depression of RPF in these subjects, at least to the levels observed on day 10, suggests that the compensation was sub-maximal relative to the capacity of the kidney observed before bed rest. The reduced compensatory response in the controls resembles the state of cardiovascular deconditioning evidenced by orthostatic hypotension and higher heart rates following periods of bed rest during tilt table experiments (McCally and Lawton, 1963).

It was mentioned earlier that the application of LBNP served to reduce the diuresis of recumbency and depression of PV. In a study of the effects of LBNP on renal function, Gilbert et al. (1966) measured RPF during the application of -60 mm mercury of LBNP. After 45 min of LBNP, RPF was decreased to 77.3 percent of resting values (a finding similar in magnitude to the effect of exercise in our study), which suggests a similar effect of exercise and LBNP on RPF. In other experiments (Lamb and Stevens, 1965; Stevens et al., 1967), the application of LBNP during bed rest was required for long periods (8-12 hours daily) in order to reverse the negative hydration and PV contraction (although a lower LBNP of -30 mm mercury was applied).

In the present study, GFR was measured during the 30 min bout of exercise by the endogenous creatinine method. Although this method has been criticized for its inherent errors, in a review by Doolan et al. (1962), the method was shown to be quite valid for 24 hour periods (a finding substantiated by the results of the present study). However, during periods as short as 30 min, with dynamic exercise and substantial alterations in renal function, the method is probably unreliable. In addition, it has been shown that creatinine secretion is inhibited in the presence of exogenous p-amino hippurate (Crawford, 1948). Therefore, a lower urinary excretion of creatinine caused by the infusion of PAH, would give an erroneously low GFR. Hence, in the present study, the absolute values for GFR during exercise are assumed to be low. However, since serum creatinine values did not vary greatly throughout the experiment and the concentration of PAH was constant in each renal function test (see Appendices II and IV, Part II), it is assumed that relative changes in GFR on each day are reliable indications of renal function during exercise.

The degree of depression in both exercisers and controls was similar on day 10. However, during bed rest the exercisers showed markedly depressed filtration rates relative to the day 10 pre-bed rest value. During recovery, their GFR was still depressed, whereas the controls showed no change from pre-bed rest values. The pattern of the exercisers' GFR can not be related to PV or RPF after bed rest, inasmuch as the latter two parameters were equal to baseline values. In addition, sodium and potassium excretion were also at baseline values during exercise on these two days of recovery, which indicates that they were unaffected by the lowered GFR. Hence, it would appear that there is no readily apparent explanation for the depression of exercise GFR observed in the present study after bed rest.

Numerous studies have demonstrated depressed sodium excretion during exercise (Kattus et al., 1949; Bucht et al., 1953; Aurell et al., 1967; Castenfors, 1967a). In addition, some of these authors have reported a significant relationship between the magnitude of depression of RPF and sodium excretion during exercise. In the present study, all exercisers demonstrated depressed exercise sodium levels on each day of measurement during bed rest. Resting excretion rates were not available during ambulatory periods, but the excretion rate after exercise during the pre- and post-bed rest periods were similar.

The depression of sodium excretion has been shown to occur with the application of LBNP (Gilbert et al., 1966). However, the magnitudes of sodium depression were greater than those seen in the present investigation. Considering the relation of RPF to sodium depression and the similar depression of RPF during LBNP and exercise, the greater depression of sodium observed by Gilbert and his colleagues is somewhat surprising. These authors reported that the administration of spironolactone failed to reduce the depression of sodium during LBNP and concluded that the depression of GFR, which occurred with and without the aldosterone antagonist, was responsible for the decreased sodium excretion. However, in the present study, the control subjects did not show a depressed GFR on day 21, yet sodium was observed to be depressed in relation to baseline levels. Conversely, the exercisers' GFR was reduced and sodium excretion was equal to baseline levels during recovery. These two observations suggest an additional operative mechanism in the regulation of sodium excretion during exercise.

In the present study, the pattern of sodium excretion during bed rest and recovery in the exercise group had a strong resemblance to PV changes. Plasma volume was decreased and sodium excretion depressed to the greatest extent during bed rest. Similarly, when PV returned to pre-bed rest values on day 19, the depression of sodium excretion was also equal to baseline values. This relationship was again exemplified by the controls who, on day 21, had a slightly lowered PV and depressed sodium excretion relative to the values on day 10. There was no relationship in the exercise group between sodium and RPF depression. However, the control group showed a larger depression of both on day 21, as compared to days 10 and 27.

Although sodium and chloride excretion followed similar patterns of depression during the first half of bed rest, sodium was reduced to only 93 percent of resting on the last day of recumbency and returned to baseline values during recovery (indicating that it must have been accompanied by some anion other than chloride on those days). The depression of chloride to a greater degree than sodium, which occurred on days 10, 19, 21, and 27, is in contrast to the observations of Kattus _et al_. (1949), who observed that chloride was depressed less than sodium during exercise.

The increased excretion of potassium in the present investigation was consistent in 12 out of 12 measurements. Such consistency is not in agreement with the observations of others, who report variable trends of potassium excretion during exercise (Kattus _et al_., 1949; Aurell _et al_., 1967; Castenfors, 1967a). However, in the study by Aurell and co-workers, an increased excretion of potassium was observed with light workloads in the supine position, whereas with heavy loads, potassium excretion was decreased. These workers utilized heart rates to classify the work as either light, moderate, or heavy. At rates of 125-150 beats/min (moderate work), potassium excretion during exercise was variable, whereas in the present study with a constant workload of 806 kpm and an average heart rate of 135 beats/min, the decreased rate of excretion was consistent. The consistently decreased sodium and increased potassium excretion during exercise suggest the possibility that sodium is exchanged for potassium by renal mechanisms during exercise.

The circulatory-respiratory response (as measured by oxygen intake, pulmonary ventilation, and heart rate) of the exercise group to a mean supine bicycle ergometer exercise workload of 806 kpm/min agrees closely with that of a sample of non-athletic young males studied by Stenberg _et al_. (1967), who exercised at a mean load of 793 kpm/min. The control group's workload was 744 kpm/min and, similarily, their response agrees rather closely with the results of Ekelund (1966), who studied a group of young men of ordinary physical fitness at a mean exercise load of 700 kpm/min. A summary of oxygen intake and heart rate values for untrained subjects of similar age (and working at a similar supine workload), reveals a similar heart rate response, but slightly higher oxygen intakes (Grimby, 1965). Thus, it would appear that the bicycle ergometer utilized in the present investigation was well calibrated, and that the subjects were not a particularly atypical group with regard to physical fitness. It would also appear that the primary reason for the higher oxygen intake (approximately 15 percent) observed in the exercisers was due to working at a heavier load. The fact that the pre-bed rest exercise heart rates were not materially different from the controls and their higher maximal oxygen intake (3.487 L vs 3.074 L) attests to their slightly superior level of physical fitness.

Decreased tolerance for physical exercise due to bed rest was first observed by Deitrick, Whedon, and Shorr (1948). Subsequent studies have verified their findings by showing a diminution in maximal oxygen intake and/or a rise in heart rate for a standard sub-maximal work task (Taylor _et al_., 1948; Birkhead _et al_., 1963; Birkhead _et al_., 1964; Cardus _et al_., 1965; Miller _et al_., 1965). Several investigators have attempted to assess whether this decreased work tolerance could be attributed to physical inactivity alone, or whether it could be entirely ascribed to maintenance of the agravity horizontal position. Birkhead _et al_. (1964) exercised two subjects on a bicycle ergometer in the horizontal position at 600 kpm/min for 1 hour/day throughout 24 days of bed rest, and found no appreciable loss in maximal oxygen intake. Cardus _et al_. (1965) found that subjects who performed isometric exercises during 14 days of bed rest showed a much smaller increase in heart rate (5.4 vs 19.5 beats/min) at standard workloads on a bicycle ergometer than those who did no exercise. Miller _et al_. (1965) exercised subjects on a simulated bicycle ergometer at easy to moderate loads for 1 hour/day during four weeks of bed rest. They observed a significant reduction in maximal oxygen intake and in length of walking time on the treadmill. Cardus (1966) found that heart rate response to a bicycle ergometer load of 120 watts (734 kpm/min) was higher after 10 days of bed rest, and almost equally increased when the subjects exercised on a stretching device for 20 min/day during bed rest.

The results of the present investigation indicate that the heart rate at the end of the standard 30 min supine ergometer ride decreased during bed rest in the exercise group, while in the control group, the post-bed rest rate was higher than that observed before bed rest. Contraindication of these findings by the observations of Miller et al. (1965) and Cardus (1966) is likely due to the type and intensity of their in-bed exercise regimens, since the results of a series of experiments reported by Rodahl et al. (1967) indicate that 1 hour/day of horizontal bicycle ergometer exercise at 600 kpm/min is sufficient to prevent loss in physical work capacity of the circulatory-respiratory system.

The effect of three to four weeks of bed rest on respiratory metabolism response to sub-maximal exercise was studied by Taylor et al. (1948), who observed that the oxygen intake for walking at 3.5 mph up a 10 percent grade for 30 min was 2.003 L before bed rest and 1.913 L after bed rest. The exercise RQ was 0.82 before bed rest and 0.93 after, while the respiratory efficiency dropped from 55.3 ml (per 1000 ml) to 46.1. Cardus et al. (1965), on the other hand, observed slightly higher oxygen intakes in his subjects for a sub-maximal bicycle ergometer ride after 14 days of bed rest, but felt that these differences were within the range of their error of estimate and were not significant. Respiratory quotient and oxygen utilization ratio (oxygen intake/pulmonary ventilation) were both slightly lower after bed rest, but the authors felt this was at least partially due to hyperventilation by the subjects during their first ergometer ride. After 14 days of bed rest with daily isometric exercise, there was a tendency toward lower pulmonary ventilation and respiratory rate, but there was no significant difference between pre- and post-bed rest values for these parameters, or for oxygen intake and RQ. Cardus (1966), in examining the effects of 3 weeks bed rest (both with and without exercise), found a reduction in oxygen intake and a rise in pulmonary ventilation and respiratory rate at HR of 160 on a bicycle ergometer test after bed rest alone. Exercise during bed rest resulted in a lowering of oxygen intake in one group with a rise in the other. Pulmonary ventilation followed a similar pattern, but the respiratory rate was unchanged in both groups of exercisers.

In the present study, other than heart rate, there was no difference between the exercise and control groups in the pattern of sub-maximal exercise respiratory response. Hence, there was no indication that the supine exercise training regimen during bed rest had any measurable effect on the subjects' sub-maximal oxygen intake, pulmonary ventilation, respiratory rate, true oxygen percent, and RQ. However, the rise in RQ observed in both groups is in agreement with the accepted principle that as physical work becomes more strenuous the RQ in work increases. Conversely, the lowered pulmonary ventilation and respiratory rate, and the higher true O_2 are in the same direction of the normal physical training effect. It is felt that the observed exercise respiratory changes are within the range of measurement error and of insufficient magnitude to indicate a positive training effect for either group. However, it should be pointed out that recovery heart rate and respiratory metabolism measures were not secured in this study, and hence, the possibility of increased anaerobic metabolism for the standard work task with bed rest for one or both groups, can not be ruled out. Also, maximal oxygen intake measurement after bed rest would have aided in presenting a more complete picture of whether there was circulatory-respiratory deconditioning for either or both groups.

PART V

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE STUDY

Summary

A 27 day experiment was designed to study the effects of 9 days of recumbency on the physiological systems related to the redistribution of body fluids, renal function, electrolyte exchange, and metabolism. An effort was made to explore the mechanisms of the pathophysiologic changes of these systems which are seen in recumbency, relate them to weightlessness, and to predict the efficacy of the procedures employed for future application to space flight. The role of standardized dynamic bouts of exercise was studied for its effects in attenuating the alterations of the affected physiological systems during bed rest.

Ten days of equilibration on a low residue diet of controlled water, electrolyte, and caloric content preceded the 9 days of recumbency. During the bed rest period, four young adult males rode on a bicycle ergometer in the supine position twice daily for 30 min, while four other young adult male subjects remained inactive. Position and activity were maintained during the bed rest period. A 7 day ambulatory recovery period, in which pre-bed rest activity patterns were resumed, with ad libitum dietary intake (but recorded by each subject), followed bed rest. Measurements taken during the 10 day equilibration period served as baseline comparisons for those taken during bed rest and recovery.

Daily measurement of water exchange revealed a slight diuresis during bed rest, with the exercise group demonstrating a much smaller increase in urinary output than the control group (10 ml and 100 ml/day, respectively). Urinary values were considered representative of water balance, as the extra renal changes in water excretion were matched by changes in fluid intake. The exercise group returned to positive water balance on the first day of recovery, whereas the control group did not regain positive balance until the third day of recovery. It was observed that water loss was an active process occurring only during the day, as night water exchanges remained unchanged during bed rest.

The exercise group's plasma volume (PV) decreased by 6 percent during bed rest; but returned to its baseline level at the end of bed rest, and remained near this level throughout recovery. The control group's PV was depressed by 11 percent midway through bed rest, remained decreased until the end of bed rest, but returned to the baseline level after one day of ambulatory recovery. Renal plasma flow (RPF) remained unchanged in the exercise group during bed rest, while the control group's RPF rose slowly to 200 ml/min higher than baseline levels. After 7 days of ambulatory activity, the controls' RPF was still elevated 100 ml/min above their pre-bed rest value.

Analysis of electrolyte metabolism revealed a balance of -122 mEq of sodium, -57 mEq of potassium, and -131 mEq of chloride in the exercise group, and -140 mEq of sodium, -152 mEq of potassium, and -271 mEq of chloride in the control group. The loss of body fluids and electrolytes in the exercise group was nearly isotonic, while in the control group, there was a larger loss of free water than solutes, resulting in a slightly hypertonic contraction of the body fluid compartments. With no apparent positive water balance during bed rest, and a nearly isotonic fluid loss, it was assumed that plasma electrolyte concentrations represent total extracellular fluid (ECF) electrolyte content. By comparing ECF electrolyte content, it was shown that the negative balances of measured electrolytes reflected their release from body reserves.

Analysis of standard calculations representing renal regulation of sodium and potassium revealed that the loss of both was not related to GFR or sodium-potassium ratios, although the retention of sodium was clearly related to a depressed GFR and sodium-potassium ratio during recovery. It was concluded that mechanisms other than those analyzed are responsible for the observed negative balances during bed rest.

In the present study, the controls demonstrated a rather steady and more clearly defined drop in basal oxygen consumption than the exercisers with bed rest. The exercisers showed no significant change in the basal heart rate as a result of bed rest. The controls, contrary to results of previous studies, showed a distinct drop in basal heart rate during much of bed rest, with an immediate increase evidenced after the first day of recovery.

Both groups lost lean body mass (LBM) during bed rest, with that of the non-exercising controls amounting to approximately three times that observed in the exercisers. There was evidence of a slight gain in fat in both groups as measured by underwater immersion, although skinfold measurements yielded conflicting results. Strength results were equivocal, as the exercisers showed no change with bed rest in grip and knee extension strength, while the controls demonstrated an increase in grip strength and a loss in knee extension strength. Both groups increased in plantar flexion strength throughout the experiment, indicating a possible "learning" effect. The vital capacity of the exercisers remained unchanged after bed rest, while the controls showed a decrease of 4 percent.

The physiological response to exercise was determined from measurements of renal function, electrolyte excretion, and respiratory metabolism. No change in RPF was noted in the exercisers. However, after 1 day of recovery, the controls had a resting level of 250 ml/min higher than their pre-bed rest value, and a depressed resting RPF during exercise of 15 percent greater than baseline values. Nevertheless, the actual value of this exercise clearance was higher than the pre-bed rest value, indicating a reduced capacity to decrease RPF during exercise. Sodium and chloride excretion patterns during exercise reflected changes in PV in the exercise group, in that excretion was depressed to the greatest extent when PV was lowest, whereas the control group showed a relationship between depression of both RPF and sodium and chloride excretion. Potassium excretion was increased during the exercise bout, suggesting its relationship to sodium retention, which occurred uniformly during exercise.

Decreased tolerance for physical exercise as a result of bed rest was evidenced by an increase in exercise heart rate in controls. The exercise group did not demonstrate any evidence of circulatory-respiratory deconditioning, as their exercise heart rates remained essentially the same throughout bed rest, while their respiratory metabolism response showed a slight change in the direction of the normally observed physical training effect. The controls exhibited a similar exercise respiratory metabolism response to bed rest.

Conclusions

An experiment designed to study the effects of weightlessness in an earthbound laboratory is inadequate in some respects. In the present study, and in many previous investigations, bed rest has resulted in a negative water balance of smaller magnitude than that which occurs in astronauts during space flights (Webb, 1967). The diuresis of recumbency is maximal within several days and the process of electrolyte loss and PV contraction seems to be somewhat arrested in an equal amount of time, as studies of bed rest of up to four weeks duration have not revealed significantly different results from studies lasting only one week. Therefore, it is not possible to speculate on the extent to which the observations made in the present experiment represent the quantitative changes which occur in space. However, inasmuch as the physiological effects of weightlessness bear many resemblances (McCally and Lawton, 1963), a qualitative analysis of the mechanisms by which the alteration of physiology occurs during bed rest appears to be well justified.

The results of the present and previous studies suggest that the diuresis of recumbency is primarily mediated by the loss of solutes, with sodium appearing to be the main component initiating the diuresis in the first 48 hours. The loss over two days is very similar to the pattern of a recumbency diuresis lasting only a few hours. The negative balance of water and electrolytes after 48 hours is insidious, with potassium and chloride losses increasing in proportion to sodium. As a negative electrolyte balance develops, the body fluid tonicity decreases with a greater capacity thereafter to lose water when large quantities are ingested. Once this stage has been reached, the immediate effects of exercise do not alter diuresis, although gravitational stimuli do reverse the water loss. In the present study, the exercise group's urinary output during bed rest indicates that a programmed regimen of moderate exercise during bed rest can attenuate (but not reverse) the loss of electrolytes and water. In addition, the loss is more nearly isotonic, whereas the body fluid losses of the control subjects consisted of more free water than solute loss, which indicates a greater depression of antidiuretic than antinatriuretic mechanisms in non-active recumbency.

The effect of exercise on antidiuretic mechanisms is open to question. A recent study by Kozlowski et al. (1968) showed that ADH activity was not increased during supine exercise and suggested that this is a result of insufficient pooling of blood in the legs to stimulate the Henry-Gauer reflex. In the present study, no depression of a water diuresis was observed during supine exercise. However, in view of the depression of RPF, increased stroke volume, and increased cardiac output in supine exercise observed by Grimby (1965), there are indications that the central blood volume is shifted to the exercising extremities. It appears, then, that the shift of blood to the extremities does not pool in the low pressure side enough to cause ADH secretion. This raises the question (which can not be answered by results of the present study) of whether exercise effects an attenuation of both water and solute loss.

In Part IV, a short review of renal hemodynamics revealed several possible mechanisms that could be responsible for the increased RPF of the controls during bed rest. The relaxation of nervous tone to the renal arterioles appears to be the most plausible explanation for this phenomenon. In effect, the immobile, recumbent state can be likened to renal denervation, in that no reflex stimulation of the circulatory system occurs. The vasomotor tone could conceivably become relaxed in such a situation (Tobian, 1967). This relaxation can be contrasted to the state of the exercisers, who twice daily underwent a condition that reduced RPF in a manner identical to that which occurs in the change from supine to upright posture in the presence of gravity.

It is difficult to relate the changes of resting RPF in the controls to electrolyte metabolism during bed rest. The most striking changes in sodium and chloride balances occurred well before the elevated RPF was apparent, while potassium losses reached a peak four days before the peak elevation of RPF. However, there was a relationship of renal circulation and electrolytes in the controls during the single bout of exercise they performed shortly after bed rest. In addition, trends of sodium and potassium excretion in both groups during exercise revealed a pattern suggestive of an association between renal circulation, PV, and the extent of electrolyte excretion or retention. These relationships might be evident only during exercise and, hence, would not represent the complete pattern over 24 hours. An alternate possibility is that they might be dependent on the circulatory reflexes which occur only during acute changes in the central blood volume. This would explain the lack of response in the controls to a reduced PV which occurred over a five day period, as opposed to the acute reduction of central blood volume which occurs during exercise. It is concluded that no definite relationship between the increased RPF and the electrolyte imbalances can be made. However, the implications of an increased blood supply and a decreased capacity to respond to exercise are strongly suggestive of a deconditioning of the hemodynamic control of the kidney, which could easily lead to further disorders in electrolyte metabolism due to the close physiological association of these two systems.

The etiology of the negative electrolyte balances in the present investigation has been attributed to the initial and substantial natriuresis which occurred during the first 24 hours of bed rest. The loss of chloride during that period was essentially equal to sodium. Thereafter, chloride losses were much greater than sodium losses, indicating that the latter was being reabsorbed in the kidney with some other anion. In addition, sodium and chloride balances substantiate the contention that sodium was associated with another anion in the ECF. Bicarbonate seems to be the most likely anion available in such a situation. The origin of this electrolyte can be related to the release of sodium from bone reserves, in that Loebeck and Forbes (1958) showed a release of 20 percent sodium and 18 percent carbonate from the bone during sodium mobilization. The addition of carbonate to the ECF would then account for the increased bicarbonate, and in addition, would suggest that the depressed titratable acidity of the controls represented a compensatory retention of hydrion. Or, conversely, the retention of hydrion as a result of increased sodium excretion and decreased exchange, as suggested by Thomas (1957), could contribute towards the formation of bicarbonate from carbonate.

As long as the caloric content of the diet is adjusted to the decreased activity level dictated by bed rest, no appreciable gain in body weight due to fat accumulation will result over periods of several weeks or longer. However, with drastically curtailed activity, muscle atrophy is quite noticeable within several weeks. In the present investigation, a small amount of LBM was lost in the exercise group, with the non-exercising controls losing approximately three times as much. In addition, no significant loss in limb girths was observed in the exercisers. Hence, it would appear that the supine exercise regimen utilized in this study is of sufficient intensity to retard significant losses in LBM. It is concluded that the use of skinfold calipers to indicate changes in body composition under similar conditions is unadvisable.

It has been observed in previous studies that prolonged bed rest results in circulatory deconditioning, as evidenced by an increased heart rate response to a standard, submaximal work task. In the present investigation, the controls demonstrated an increase in heart rate response to exercise, which was not seen in the exercisers. Both groups showed only slight changes in respiratory metabolism measures, but in the direction of the normal physical training effect. It is felt that the observed exercise respiratory changes are within the range of measurement error and of insufficient magnitude to indicate a positive training effect.

The comparison of the lower body negative pressure (LBNP) to supine exercise in the chronic and acute forms has shown that these two procedures have similar effects on circulatory function (Gilbert _et al._, 1966; Stevens _et al._, 1966), although the reason is not readily apparent. According to the classification of Gauer and Henry (1963), LBNP would seem to be mainly related to the low pressure side of the circulation, with an increase in the capacitance of the lower body venous system. On the other hand, supine exercise would seem to involve the higher pressure side (arterial circulation) with increased blood flow to the extremities and little change in the capacitance of the venous system. Henry and Gauer postulated that each condition involves different receptors for volume, with the primary baroreceptor in the capacitance side of the circulation effecting ADH secretion, and the high pressure or resistance side effecting salt retaining mechanisms. The recent report by Rogge and Moore (1968) confirms the increase of ADH during LBNP, and the report of Castenfors (1967c) gives some support to the possibility of mineralocorticoid release during supine exercise. However, in view of the possibility of two different mechanisms in LBNP and supine exercise, the similarity of renal function, electrolyte, and water excretion in both procedures suggests that there might be an overlapping of stimuli to the low and high pressure sides of the circulatory systems. The effect of LBNP on renal function during chronic application would serve to explain the degree to which it resembles exercise in this respect.

Suggestions for Future Research

The effect of LBNP needs to be examined further to ascertain if it can be used as a cardiovascular system maintenance procedure during space flight. A study of its effect on renal circulation, and on electrolyte metabolism would clarify the efficacy of this procedure in the maintenance of water balance and electrolyte exchange. In addition, the effect of a regimen of either chronic LBNP or short bouts of moderate or severe daily exercise would serve to demonstrate if, indeed, the latter procedure is necessary for circulatory function maintenance. Although exercise has not been shown to prevent orthostatic hypotension, it has been shown to prevent the degeneration of circulatory-respiratory function in bed rest of 7 to 21 days. Hence, examination of the effects of LBNP and moderate to severe exercise over longer periods of time would appear to be an appropriate avenue for future investigation. In a recent review, Hattner and McMillan (1968) have discussed the necessity of weight bearing in the maintenance of skeletal composition. Brannon, Rockwood, and Potts (1963) have indicated that daily exercise during prolonged periods of bed rest (up to 60 days) can greatly curtail loss of musculo-skeletal function. Hence, the examination of appropriate exercise regimens to satisfy this criteria would seem to be in order.

The nature of the electrolyte imbalances, as delineated in the present study, needs to be more thoroughly investigated. If the loss of water is secondary to the loss of solutes, the problem should be examined with respect to the etiology of the electrolyte loss. Direct measurement of exchangable sodium and potassium throughout periods of bed rest (or other analogs of weightlessness) and before and after space flights, would clarify the nature of the natriuresis observed in several bed rest studies. Presently it is unknown if such a natriuresis also occurs during weightlessness. Although Lynch, Jensen and Stevens (1967) observed a slight rise in plasma pH during bed rest, to the best of our knowledge the bicarbonate-chloride ratio has not been studied in regard to the above conditions. If an increased serum bicarbonate concentration occurs during bed rest, it would indicate that the presence of an acid-base imbalance may be related to the loss of other electrolytes.

At present, there have been no indications that renal function has been measured following space flights. Inasmuch as the renal blood flow contains some 15 percent of the cardiac output available for delivery to the central circulation during situations of cardiovascular challenge (Grimby, 1965), it would seem important to ascertain whether renal-vascular deconditioning occurs during space flights. In addition, the implications of such deconditioning should be examined with respect to electrolyte metabolism.

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